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FACILITY FORM 502

N65-25599
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283
(PAGES)

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LASERS AND MASERS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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LASERS AND MASERS

A CONTINUING BIBLIOGRAPHY

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Scientific and Technical Information Division

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Each entry in the bibliography consists of a citation and abstract. The listing of entries is arranged in two major groups. All report literature references appear in the first group and are subdivided according to their date of announcement in *TPA* or *STAR*. The second group contains all published literature references subdivided according to their date of announcement in *IAA*. All reports and articles cited were introduced into the NASA Information System during the period January, 1962–February, 1965. Supplements to this bibliography will be issued if user response is sufficient and future references accumulate to an acceptable level.

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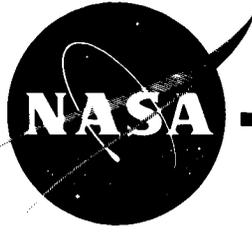
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Lasers and Masers

A CONTINUING BIBLIOGRAPHY

MAY 1965

1962

TPA ENTRIES

N62-11348 National Bureau of Standards, Washington, D.C. **PAPERS ON THE SYMPOSIUM ON COLLISION PHENOMENA IN ASTROPHYSICS, GEOPHYSICS, AND MASERS [BOULDER, COLO., JUNE 16, 1961].**

Dec. 1961. 30 p.

(PB-161625; NBS Tech. Note 124)

CONTENTS:

1. **ASTROPHYSICAL PROBLEMS.** Michael Seaton (University Coll., London). p. 3-9.
2. **COLLISION PROCESSES IN THE HIGH ATMOSPHERE.** A. Dalgarno (Queens U., Belfast). p. 10-19.
3. **SOME PROBLEMS CONNECTED WITH THE ANALYSIS OF THE STRUCTURE OF THE SOLAR ATMOSPHERE.** Charlotte Pecker (Inst. of Astrophysics, Paris). p. 20-30.

N62-13148 Electronics Research Lab., U. of Calif., Berkeley. **PARAMAGNETIC MASER OSCILLATOR ANALYSIS.**

S. Wang and J. R. Singer. Sept. 8, 1962. 22 p. 11 refs.

(Contract AF 49(638)-102)

(Inst. of Engineering Research Series No. 60, Issue No. 402; AFOSR-2340)

A physical and mathematical description of a maser oscillator is given with particular emphasis upon explaining the structure of the output line shape. Several approaches to the problem are taken. A qualitative description of the motion of the spin vector is followed by a derivation of the equations pertinent to the interaction of a tuned circuit (microwave cavity) and precessing spins. The resultant equation is nonlinear. Approximate solutions are given, and these are plotted as output amplitude vs. time. In addition, the equations are solved with numerical solutions for specific experimental conditions by means of a digital computer. The field-swept oscillator line shapes are explained by the analysis, and the steady state oscillator is described as well.

(Author Abstract)

N62-13916 Technical Research Group, Syosset, N.Y. **RESEARCH ON PROPERTIES OF LASER DEVICES. VOL. II: APPENDICES.**

R. Daly, G. Gould, G. Grosf, B. Hammond, S. Jacobs, R. Martin, M. Newstein, R. Rabinowitz, J. Sjoblom, N. Solimene, R. Targ, and S. Winsberg. July 2, 1962. 185 p. refs. For Vol. I see N62-13915 11-21.

(Contracts AF 49(638)-673 and Nonr-3787(00); ARPA Order 6-58) (TRG-134-TR-7, Vol. II)

CONTENTS:

- A. **MODES OF RESONATOR WITH PIN-HOLE SUPPRESSOR.** 13 p.
- B. **AMPLIFIER PERFORMANCE (Single Pass).** 32 p.
- C. **PULSE OSCILLATOR PERFORMANCE.** 47 p.
- D. **ENHANCEMENT IN MERCURY-KRYPTON AND XENON-KRYPTON DISCHARGES.** 12 p.
- E. **BATES-DAMGAARD CALCULATIONS OF A-VALUES FOR SOME TRANSITIONS IN ZN^I.** 22 p.
- F. **CONFOCAL AND NON-CONFOCAL RESONATORS AT LASER WAVELENGTHS.** 29 p.
- G. **RUBY OUTPUT—PROGRESS REPORT NO. 1.** 14 p.

N62-14658 Heinrich-Hertz-Institut, W. Berlin (Germany).

RESEARCH ON RUBY AND AMMONIA MASER AMPLIFIERS. F. W. Gundlach. In *Low Noise Electronics; Proc. of the Fifth AGARD Avionics Panel Conf., Oslo, 31 July-2 Aug. 1961.* p. 189-199. (See N62-14643 13-21)

Theoretical considerations on an r.f.-equivalent circuit for a reflection type cavity maser are given by which stability, gain and bandwidth may be calculated. Constructional details of an ammonia-beam-maser and of a four-level push-pull ruby-maser and some experimental results are given.

(Author Abstract)

N62-14659 Compagnie Générale de Télégraphie sans Fil, Paris (France).

INFLUENCE DES CIRCUITS HYPERFRÉQUENCES SUR LES PERFORMANCES D'UN MASER À CAVITÉS COUPLÉES [INFLUENCE OF HYPERFREQUENCY CIRCUITS ON THE PERFORMANCES OF A MASER WITH COUPLED CAVITIES].

G. Broussaud and L. Malnar. In *Low Noise Electronics; Proc. of the Fifth AGARD Avionics Panel Conf., Oslo, 31 July-2 Aug. 1961.* p. 200-224. In French. (See N62-14643 13-21)

The performance analysis of a maser-type amplifier, with coupled cavities, is treated by means of wave propagation of the form, $\exp(-ikz + akz)$. The total calculation is made for one-, two-, and three-symmetric, synchronous cavities. In each case the problem is examined for the aspect of stability, the passband, and the equivalent input temperature. Examples are given utilizing a ruby in the X-band.

(Author Abstract trans P.F.E.)

N62-14660 Mullard Research Labs., Mullard Radio Valve Co., Ltd., Redhill (Gt. Brit.)

TRAVELLING-WAVE MASERS.

J. C. Walling. In *Low Noise Electronics; Proc. of the Fifth AGARD Avionics Panel Conf.*, Oslo, 31 July-2 Aug. 1961. p. 225-234. 11 refs. (See N62-14643 13-21)

The background theory of the TWM is outlined, and the design, construction and performance of an S-band TWM using ruby as the active material is described. The importance of cross relaxation processes in maser operation is pointed out. Applications of the TWM in the fields of communications, radio astronomy and radar are discussed. (Author Abstract)

N62-14661 Quantatron, Inc. Applied Physics Labs., Santa Monica, Calif.

SOLID STATE LASER AND IRASER STUDIES.

T. H. Maiman. In *Low Noise Electronics; Proc. of the Fifth AGARD Avionics Panel Conf.*, Oslo, 31 July-2 Aug. 1961. p. 236-249. 10 refs. (See N62-14643 13-21)

The pumping power requirements for three-level and four-level solid state laser and iraser systems are presented. The pertinent material parameters and properties of exciting lamps are discussed. The discussion is illustrated by calculating the relevant quantities applicable to ruby. (Author Abstract)

N62-14666 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena. **A MASER SYSTEM FOR RADAR ASTRONOMY.**

Walter H. Higa. In *Low Noise Electronics; Proc. of the Fifth AGARD Avionics Panel Conf.*, Oslo, 31 July-2 Aug. 1961. p. 296-304. 3 refs. (See N62-14643 13-21)

A description is given of a maser system for use in radar astronomy and space communications. The equipment has been used successfully in a Venus radar experiment. A ruby maser of a particularly simple design is described, and the problems associated with the operation of such a maser on an antenna are discussed. The dewar system was unique in that it was demountable. The duty time of one filling of cryogenic liquids was in excess of 24 hr, and it is expected that the maser will operate continuously for 12 weeks.

In order to achieve a good noise figure for the system, the maser was followed by a parametric amplifier; this is believed to be the first such application for a parametric amplifier. Gain and noise measurements are made by use of a set of remote-controlled switches from the control building. (Author Abstract)

N62-15473 Air Force Cambridge Research Labs. Electronics Research Directorate, Bedford, Mass.

RADIATION PATTERNS AND AXIAL MODES OF RUBY LASERS.

C. M. Stickley and R. A. Bradbury. June 1962. 47 p. 108 refs. (AFCL-62-386)

The present state of the art in optical processing of the flat ends of the ruby laser rod can seriously limit the performance of the laser; however, if the crystal is basically of poor quality, improvement of the flatness and parallelism of the ends will have little effect on its beamwidth and near and far field radiation pattern. This has been verified by experiment. Far field radiation patterns are partially understood in that (a) they are Fabry-Perot patterns; (b) ring patterns from all axial modes virtually overlap; and (c) the rings are wide partially due to optical path-length variations in the crystal. If optical path-length differences through the laser rod of greater than one wavelength exist, a Fabry-Perot ring pattern will not develop in the far field, but the radiation will still be partially coherent as determined by performing Young's experiment. The axial modes in ruby have been separated optically and their separation agrees with basic theory within the limits of experimental error. (Author Abstract)

N62-15636 Los Alamos Scientific Lab., N. Mex.

PULSED RUBY LASER FOR PLASMA INTERFEROMETRY.

D. E. Nagle, A. S. Rawcliffe, F. L. Ribe, and S. A. Schleusener. Sept. 11, 1962. 26 p. 3 refs. (Contract W-7405-eng-36) (LAMS-2734) OTS: \$0.50.

The construction and operation of a pulsed ruby laser are described. In this device the optical path of the photons between external mirrors is blocked by a biased Kerr cell as the ruby is optically pumped above threshold. A pulse to the Kerr cell then releases a single "giant" pulse of photons. A maximum power of 24 kw and a pulse duration of 0.1 μ sec have been obtained. It is intended to apply this light source to fast plasma interferometry for the determination of plasma cross-sectional shape and electron density with good time resolution. (Author Abstract)

N62-16182 Army Signal Missile Support Agency, White Sands Missile Range, N. Mex.

THE GROWTH OF A LASER ACTION IN A LASER CRYSTAL.

Judd Q. Bartling. Aug. 1962. 20 p. 6 refs. (EID-123)

A nonlinear differential equation is derived for the electric field strength in a laser. A composition of classical electromagnetic theory and quantum mechanics is used in the derivation. (Author Abstract)

N62-16183 Army Signal Missile Support Agency, White Sands Missile Range, N. Mex.

AN OPTICAL FREQUENCY RADAR.

Judd Q. Bartling. Aug. 1962. 42 p. 13 refs. (EID-122)

This report discusses the advantages of a radar operating at optical frequencies over a radar operating conventional frequencies. A theoretical system is developed to determine the feasibility of such a system to measure range, velocity, and acceleration; and included are the errors that would be inherent in the system. The optical radar theoretically developed here is for targets under 2,000 feet in altitude. Also it is shown how this system could be made to track a target automatically. (Author Abstract)

N62-16275 Solid State Materials Corp., East Natick, Mass.

INVESTIGATION OF THE GROWTH OF OPTICAL CRYSTALS. Final Report.

J. B. Schroeder. July 31, 1962. 14 p. (Contract AF 19(604)-8846) (AFCL-62-593)

Experimental work aimed at developing techniques capable of growing optical quality crystals for solid state laser applications is described. The program was confined to the growth of doped crystals of Al_2O_3 , CaF_2 , BaF_2 , $PbMoO_4$ and $CaWO_4$. Rubies (chromium doped sapphire) were grown by the Verneuil method. Most of the crystals were grown on 60° seeds until it became evident that the 90° orientation was preferable for optical masers because of anisotropy in both the absorption and emission of the chromium ion in the sapphire host. Both CaF_2 and BaF_2 crystals could be grown in a resistance heated inert atmosphere furnace with both samarium and uranium dopings if no trace of oxygen was present in the system. The normal segregation of uranium in CaF_2 was overcome by using a floating crucible. Examination of thin sections of these crystals frequently showed precipitate particles, which may account for the observed variations in threshold power for $CaF_2(U^{3+})$ lasers. Small crystals of $PbMoO_4$ and $CaWO_4$ were grown from a noble metal crucible heated by coupling to a rf generator. When a slight excess of MoO_3 or WO_3 was added

to the melt, uniformly doped crystals, free of scatter centers, were grown by pulling up half the melt at less than $\frac{1}{4}$ in/hr. After annealing to remove the residual strains, low threshold maser action has been consistently observed in confocal rods fabricated from such crystals. (M.P.G.)

N62-16763 Space Technology Labs., Inc., Redondo Beach, Calif.

MASERS AND LASERS: A BIBLIOGRAPHY.

J. F. Price and A. K. Dunlap. June 1962. 167 p. 1294 refs. (Research Bibliography 41; Rept. 9990-6052-KU-R01; AD-274-843)

This bibliography is composed of approximately eight hundred maser references, five hundred optical maser (laser) references, and additional references on irasers, frasers, and rasers. The bibliography also includes an author index, originating agency index, periodical index, and an ASTIA index. (J.R.C.)

N62-17114 Army Signal Research and Development Lab., Fort Monmouth, N. J.

FAST RESPONSE SOLID STATE PME DETECTOR FOR LASER SIGNALS

A. Boatright and H. Mette. In Office of the Chief of Research and Development Army Research Office, Washington, D. C. Proc. of the 1962 Army Science Conf., West Point, N. Y., June 20-22, 1962 Vol. I Sept. 19, 1962 p 31-46 2 refs (See N62-17113 18-01)

A solid state light detector, based on the photomagnetolectric effect in germanium, was developed which is capable of overcoming some of the difficulties encountered with photomultipliers as light demodulators. It is shown that a photomagnetolectric detector of considerable sensitivity, and with fast response times, can be fabricated and used as fast response demodulators of modulated light. The fine structure of laser signals can also be investigated by the use of this detector. J.R.C.

N62-17338 Stanford U., Calif.

COHERENT LIGHT FOR COMMUNICATIONS

Arthur L. Schawlow. In Proc. of the IAS National Symp. on Tracking and Command of Aerospace Vehicles, San Francisco, Feb. 19-21, 1962 p 152-156 5 refs (See N62-17322 18-09) IAS: \$5.00 members, \$10.00 nonmembers

A discussion is given on the optical maser and its possible advantage for space communications. The advantage of using light waves for communications arises from two properties: (1) the frequency of light is very high, of the order of 10^{14} cycles per second, so that it is possible to have very wide bandwidths; and (2) the light waves for communication are very short, which means that with antennas of moderate size it is possible to get an extremely directional beam. The antenna aiming and quantum noise problems connected with coherent light communications are discussed. J.R.C.

N62-17348 Aerospace Information Div., Washington, D.C.

LASER PATENT

Oct. 18, 1962 1 p Review of; V. A. Fabrikant, M. M. Vudynskiy, and F. A. Butayeva Patent no. 148441 A method for the Amplification of Electromagnetic Radiation Zh. Izobert., no. 13, 1962, p 20 (AID-62-168) OTS: \$1.10 ph, \$0.80 mf

This Russian patent covers a method of amplifying electromagnetic radiation based on media with a negative coefficient of absorption and distinguished by the application of a multiple passage of the signal through the amplifying medium in order to increase gain. Author

N62-17507 Army Signal Research and Development Lab., Fort Monmouth, N.J.

LASER PROGRESS AND APPLICATIONS

Harrison J. Merrill. In Office of the Chief of Research and Development Army Research Office, Washington, D.C. Proc. of the 1962 Army Science Conf., West Point, N.Y., June 20-22, 1962 Vol. II Aug. 28, 1962 p 89-102 7 refs (See N62-17504 19-01)

The development of high peak power output has made the LASER attractive as a ranging device so that progress and applications for this low noise amplifier are reviewed. The LASER incorporates the advantages of the radar pulse with a very narrow beam that can be sighted optically to clear unwanted targets. Potentially, the biggest use for the LASER is in communications; a coherent light beam has a frequency of four orders of magnitude greater than a centimeter radio wave. Other potential uses of the LASER include power transmission, illumination, guidance and control, surgery, microwelding, drilling and machining. V.D.S.

N62-17633 Little (Arthur D.) Inc., Cambridge, Mass.

RELIABLE, CONTINUOUS, CLOSED-CIRCUIT, 4K REFRIGERATION FOR A MASER APPLICATION

Thomas E. Hoffman [1962] 28 p 3 refs Presented at the 1962 Cryogenic Engineering Conference, Los Angeles, Aug. 14-16, 1962

Recent advances in technology have resulted in the development of several devices requiring continuous, closed-circuit refrigeration in the region of 4K. The maser is such a device, and its recent incorporation in actual operating systems has created a demand for reliable operational refrigeration equipment for these extremely low temperatures. An actual, planned application of refrigeration equipment for cooling a maser in the Bell System's satellite communications experiment is described, and the factors affecting the design philosophy of this equipment are discussed. The refrigeration equipment designed and built for this application is described, and a schematic diagram and photographs are shown. Test results as they apply to the overall system requirements are discussed, and conclusions are given covering the program. Author

N62-17890 Bell Telephone Labs., Inc., Murray Hill, N. J.

THE RUBY OPTICAL MASER AS A RAMAN SOURCE

S. P. S. Porto [1962] 4 p 2 refs Presented at the Intern. Conf. on Spectroscopy Xth Colloquium Spectroscopicum Intern., Maryland U., College Park, June 18-22, 1962 Sponsored by the Society for Applied Spectroscopy; Maryland U.; and the International Union of Pure and Applied Chemistry (Paper No. 75) Available from Spartan Books, 6411 Chillum Pl., Wash. 12, D.C.

The use of the pulsed ruby optical maser as a Raman source was proven successful. The advantages of this over other sources are: 1) its high instantaneous intensity, 2) its monochromaticity, 3) its color (for particular applications), and 4) its parallelism. Its disadvantages are: 1) its pulsed operation, 2) the temperature shift of the wavelength of the maser radiation, 3) the appearance in the maser output of weak lines such as the N lines and others, resulting from the interaction of the light and the maser crystal itself. Ways to obtain maximum output out of the ruby are discussed, as well as the problem of obtaining continuous operation for the different three and four levels solid state materials. Some of these data are compared with the data available for the gas masers. Author

N62-17893 National Research Council of Canada. Div. of Pure Physics, Ottawa

SPECTROSCOPIC STUDIES WITH THE RUBY OPTICAL MASER

B. P. Stoicheff [1962] 17 p 16 refs Presented at the Intern. Conf. on Spectroscopy Xth Colloquium Spectroscopicum Intern., Maryland U., College Park, June 18-22, 1962 Sponsored by the Society for Applied Spectroscopy; Maryland U.; and the International Union of Pure and Applied Chemistry (Paper No. 65) Available from Spartan Books, 6411 Chillum Pl., Wash. 12, D.C.

A radically new light source—the optical maser—has recently become available for spectroscopic studies. The emission from such a light source is characterized by its high intensity of coherent and extremely monochromatic light in a narrow beam. Some of these properties are obviously highly desirable in special fields of spectroscopic research, and it seems worthwhile to investigate the potentialities of masers in such studies. It is the purpose of this paper to review briefly the present achievements in the development of maser sources and in particular to describe the pertinent optical characteristics of the ruby maser and to discuss its possible use in spectroscopy along with some preliminary results that have already been obtained.

Author

N62-17905 Naval Ordnance Lab., White Oak, Md.

THE EMISSION MODE PATTERNS OF RUBY LASERS

E. S. Dayhoff [1962] 16 p 3 refs Presented at the Intern. Conf. on Spectroscopy Xth Colloquium Spectroscopicum Intern., Maryland U., College Park, June 18-22, 1962 Sponsored by the Society for Applied Spectroscopy; Maryland U.; and the International Union of Pure and Applied Chemistry (Paper No. 51) Available from Spartan Books, 6411 Chillum Pl., Wash. 12, D.C.

When a ruby laser is subjected to a suitable flash of pumping light the crystal emits by oscillating in one or more normal modes of electromagnetic oscillation. Such modes should be distinguishable from each other by the transverse distribution of light intensity which appears across the face of the crystal. A camera making framed sequential photographs at rates around 10°/sec was used to photograph the end faces so as to study the interrelationship of successive modes. None of the situations observed so far appear to resemble the simple picture of a crystal radiating a uniform plane wave. The radiated light generally forms a pattern of small spots which changes from μsec to μsec . In some pictures a geometrically symmetrical arrangement of spots, frequently in an arc, is seen.

Author

1963 STAR ENTRIES

N63-10250 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena **AN OPERATIONAL 960-Mc MASER SYSTEM FOR DEEP-SPACE TRACKING MISSIONS**

T. Sato and C. T. Stelzreid Repr. from IRE Trans. on Space Electronics and Telemetry, June 1962 p 164-170 11 refs (NASA Contracts NAS7-100 and NASw-6) (JPL-TR-32-306)

An operational 960-mc low-noise receiving system for use in deep-space tracking missions is described. A ruby-cavity maser, low-noise antenna, low-loss transmission line connecting the antenna to the maser and associated instrumentation all combine to yield reliable and low-noise performance. Results of tests on this system in preparation for the Ranger RA-3 lunar probe are presented. The system was successfully used during operations with RA-3. A minimum system temperature of 47°K has been achieved.

Author

N63-10461 California U., Livermore. Lawrence Radiation Lab. **LASERS, A BIBLIOGRAPHY**

Carl J. Wensrich Jan. 1962 16 p 129 refs (Contract W-7450-eng-48) (UCRL-6769) OTS: \$0.50

This bibliography on Light Amplification by Stimulated Emission of Radiation is compiled from the journal literature with few exceptions. All the standard library sources were used.

Author

N63-11035 Air Force Cambridge Research Labs. Electronics Research Directorate, Bedford, Mass.

ON THE POSSIBILITY OF OBSERVING LASER ACTION FROM THE R₂ LINE IN RUBY Research Report

C. Martin Stickley Sept. 1962 12 p 4 refs (AFCRL-62-716)

Normal laser action in ruby occurs only from the R₁ line (6943Å). From a knowledge of the absorption coefficients of the R₁ and R₂ lines, it is shown that it is theoretically possible to obtain oscillation from only the R₂ line (6929Å) at room temperature by using end-mirrors that have low reflectivity at 6943Å but high reflectivity at 6929Å. Oscillation at the R₂ line is not observed when broadband reflectors (silver) are used due to its strong coupling to the R₁ line.

Author

N63-11436 Technical Research Group, Syosset, N.Y.

RESEARCH ON PROPERTIES OF LASER DEVICES Second Quarterly Technical Summary Report, September 1962 through November 1962

M. Newstein and S. Rothberg, eds. [1962] 81 p refs (Contract AF 49(638)-673; ARPA Order 356-62) (TRG-134-QTR-2)

The variation of power output from a gaseous LASER when the frequency is scanned over the Doppler lineshape has been studied. A theory of perturbed cavities has been applied to the case of small curvature. An analysis has been made of the fluctuations in the output of a quantum detector of arbitrary quantum efficiency preceded by a LASER amplifier. Work continues on the development of optically pumped cesium gas LASERs designed to operate in the milliwatt range at 3 μ and 7 μ . The study of the possibility of utilizing photodissociated TlBr as a gaseous LASER medium was pursued. Crystalline and glassy media for rare-earth ions were studied. Oscillation has been achieved in a LASER cavity consisting of crossed roof prisms. Measurements of flashlamp absolute spectral brightness, available stored energy in ruby rod, and output pulse radiant energy have been made in order to determine the division of the overall efficiency of pulse ruby oscillators.

Author

N63-11555 Massachusetts U. Polymer Research Inst., Amherst **THE USE OF A LASER AS A LIGHT SOURCE FOR PHOTOGRAPHIC LIGHT SCATTERING FROM POLYMER FILMS**

Marion B. Rhodes, Daniel A. Keedy, and Richard S. Stein June 25, 1962 6 p 3 refs (Contract Nonr-3357(01)) (ONR-TR-46)

A method is described for measuring light scattering from polymer films with a laser light source. This method greatly reduces the exposure time required for the conventional mercury arc light source, e.g., a 4-day exposure reduced to 1-laser flash. Scattering measurements taken in succession with this method can be used to follow time-dependent processes such as crystallization rates, orientation relaxation, annealing, and changes accompanying dynamic strain.

R.C.M.

N63-11672 Technical Research Group, Syosset, N.Y.

RESONANCES OF THE FABRY-PEROT LASER Scientific Report No. 1

S. R. Barone Oct. 1962 64 p 7 refs (Contract AF 19(604)-8817) (AFCRL-62-778)

The optical mode structure of a Fabry-Perot interferometer-resonator composed of two infinite strip mirrors is investigated from the general theory of nonspectral resonances. It is shown that the classical description of this configuration is inadequate to describe its response to highly monochromatic LASER radiation and must be supplemented by a discussion of the transverse resonance behavior. This introduces a fine structure to the classical Fabry-Perot rings, and implies a discrete resonance behavior for the Fabry-Perot interferometer. In analogy to the characterization of quantum mechanical virtual levels by wave functions and complex energies, it is convenient to characterize the discrete resonances of a Fabry-Perot by mode functions and complex resonant frequencies. It is shown that, in the high-frequency limit, the open sides of the structure can be replaced by an effective impedance boundary condition. The solution of an elementary resonance problem then yields analytic approximations for the mode shapes, characteristic oscillation frequencies, and modal lifetimes. In the common domain of validity, these results are in excellent agreement with previous numerical work on this problem.

Author

N63-12746 California U., Berkeley, Electronics Research Lab.

THREE-LEVEL MASER MATERIALS: A SURVEY OF POTENTIAL MATERIALS, I

J. Wakabayashi Mar. 7, 1962 82 p 80 refs
(Contract AF 49(638)-102)
(IER Ser. 60, Issue 439)

A review is given of paramagnetic resonance in crystals, the relationship between the material parameters and maser performance, and potential crystals for three-level masers.

B.J.C.

N63-13094 Columbia Radiation Lab., New York, N.Y.

RESEARCH INVESTIGATION DIRECTED TOWARD EXTENDING THE USEFUL RANGE OF THE ELECTROMAGNETIC SPECTRUM Twelfth Quarterly Progress Report, Sept. 16, 1962 through Dec. 15, 1962

R. Novick et al Dec. 15, 1962 70 p refs
(Contracts DA-36-039-SC-7830 and DA-36-039-SC-90789)

Evidence has been found for the existence of the $(1s\ 2s\ 2p)^4\ P_{5/2}$ metastable state of the lithium atom. This state decays by autoionization with a lifetime of about $10\mu\text{sec}$. In addition to its intrinsic interest, this state and similar states in other atoms warrant study because they may serve as useful sources of polarized electrons and ions. Final results are reported on the magnetic moment of O^{15} . Precise values for the zero field hyperfine intervals and the level crossing fields of $245\ \text{day}\ \text{Zn}^{65}$ are reported. The spin, magnetic moment, and quadrupole moment of $43\ \text{day}\ \text{Cd}^{115m}$ have been determined by optical double resonance. Theoretical calculations of the moments of the cadmium and zinc isotopes have been made on the basis of the configuration mixing model; these are compared with the experimental values. New precise values of the HDS molecular parameters have been deduced from the measurements reported previously. Initial results are reported on the optical maser spectroscopy program. In the cooperative radioastronomy program with the Naval Research Laboratory, it has been found that the $3200\ \text{mc/sec}$ radiation from Saturn is linearly polarized and that the magnetic poles of Saturn appear to be located in the equatorial plane of the planet.

Author

N63-13754 Ohio State U. Research Foundation. Antenna Lab., Columbus

MEASUREMENT OF THE PROPERTIES OF LASER CRYSTALS AT SUBMILLIMETER WAVELENGTHS

R. F. Rowntree and W. S. C. Chang Dec. 31, 1962 34 p 37 refs
(NASA Grant NsG-74-60)
(Rept. 1093-11) OTS: \$3.60 ph, \$1.22 mf

Since many crystals have strong lattice absorption bands in the far-infrared, one of the most important steps in developing a sub-millimeter maser is to measure the dielectric properties of laser materials; this determines their effect on possible laser operation. A description is given of the measurement of the optical constants of these laser materials in the wavelength range from 100μ to $1\ \text{mm}$ by means of a special far-infrared spectrometer using an interferometric modulator as the "order sorter." The index of refraction and the absorption coefficient at $300^\circ\ \text{K}$ and $90^\circ\ \text{K}$ of the single-crystal materials such as CaWO_4 and MgO are presented. Rough experimental data on the other crystals such as Al_2O_3 and CaF_2 are discussed briefly.

Author

N63-13815 Watkins-Johnson Co., Palo Alto, Calif.

RESEARCH ON GASEOUS OPTICAL MASER TO DEVELOP HIGH CONTINUOUS WAVE POWER AT OPTICAL WAVELENGTHS Interim Engineering Report No. 3, for the Period 1 November 1962 through 31 January 1963

S. E. Sobottka [1963] 17 p
(Contract AF 33(616)-8986)
(W-J-63-606R12)

Two gridded two-region laser tubes have been fabricated and operated. The first tube was short-lived because of imperfections in the grid, the second one is presently the subject of study. Some single-pass gain measurements have been made on the second tube, with positive gain having been observed in the discharge region outside the grid, but no gain as yet having been measured inside the grid. More RF excitation power will be necessary for further measurements, and extensive measurements of gain as functions of gas pressures must yet be made.

Author

N63-14339 Johns Hopkins U. Carlyle Barton Lab., Baltimore, Md.
CROSS RELAXATION IN NON-ZEEMAN SPIN SYSTEMS Technical Report

Jan M. Minkowski Feb. 1963 180 p 36 refs
(Contract AF 33(616)-6753)
(AF-101)

The theory of cross relaxation in diluted spin systems is investigated. To subject the theory to a quantitative comparison with the results of the experimental study of a non-Zeeman spin system, previous techniques of computing the moments of the line shapes are modified. This new method gives the $2n$ -th moment of cross-relaxation lines as a polynomial of the n -th order in the concentration f of the paramagnetic ions. The order of the polynomial in f is shown to be independent of the order of the cross-relaxation process. The leading term in all of the moments is concentration independent and it can be determined with much less labor by the technique presented below than by any of the earlier methods. The new technique is applied to show that the moments of the line shape of paramagnetic lines are also polynomials in f , but the concentration independent terms are missing. The reasons underlying this difference in f -dependence of the paramagnetic and cross-relaxation line shapes are discussed.

Author

N63-14359 Baird-Atomic, Inc., Cambridge, Mass.

RESEARCH IN INFRARED INTERFEROMETRY AND OPTICAL MASERS, VOLUME 1 Final Report [Mar. 1, 1957-Aug. 31, 1962]

Bruce Billings Bedford, Mass., Geophysics Research Directorate, Feb. 21, 1963 44 p refs For Volume II see N63-14360 10-25
(Contract AF 19(604)-2264)
(AFCL-63-288)

The report is broken into two distinct and independent sections. The first section deals with the interferometric spectroscopy studies performed during the early years of this program, and includes results and conclusions. The second section deals with the maser research performed during the last six months of this program, and

includes theoretical considerations of photons in a laser cavity, techniques for isolating a single photon state, macroscopic effects associated with circularly polarized operation of a laser, and conclusions. Author

N63-14360 Baird-Atomic, Inc., Cambridge, Mass.

RESEARCH IN INFRARED INTERFEROMETRY AND OPTICAL MASERS, VOLUME II Final Report [Mar. 1, 1957-Aug. 31, 1962]

Bruce Billings Bedford, Mass., Geophysics Research Directorate, Feb. 21, 1963 26 p 9 refs For Vol. I see N63-14359 10-25 (Contract AF 19(604)-2264) (AFCLR-63-288)

N63-14422 Services Electronics Research Lab., Baldock (Gt. Brit.)
PULSED GASEOUS MASER

H. A. H. Boot and D. M. Clunie *In its* S.E.R.L. Technical Journal, Vol. 13, No. 1 Feb. 1963 p 42-43 4 refs Submitted for Publication (See N63-14414 10-01)

Molecular dissociation is proposed as the mechanism causing oscillations observed after the excitation pulse in optical gaseous masers. These oscillations were observed, following a pulsed RF or d.c. discharge in helium mixed with either neon or carbon monoxide, at wavelengths of 1.153μ and 1.069μ , respectively. In the helium/neon mixture, the oscillation reached a peak power of over 1 watt; in the helium/carbon-monoxide mixture, the peak power observed was 0.7 watts. These unusually high powers are thought to be due to the ease with which a high density of 2^3S metastable helium atoms is formed during the recombination of a well-ionized plasma; further, the high metastable density is obtained without a correspondingly high electron density. Conditions favoring resonant exchange processes are demonstrated for both neon and carbon monoxide. A similar oscillation noted in excited helium/carbon monoxide at the 1.454μ wavelength corresponding to the $3s^1P^0$ level is considered as further evidence that these oscillations are produced by selective population due to a dissociative mechanism and not by direct electron excitation. M.P.G.

N63-14545 Technical Research Group, Syosset, N.Y.

RESEARCH ON PROPERTIES OF LASER DEVICES Third Quarterly Technical Summary Report, Dec. 1962-Feb. 1963
M. Newstein and S. Rothberg, eds. [1963] 174 p 53 refs (Contract AF 49(638)-673; ARPA Order-356-62; Proj. Defender) (TRG-134-QRT-3)

Analytic work continued on the study of the variation of the power output versus frequency for a Doppler line shape, and on the modes of laser cavities. Oscillation at 3.2μ has been achieved in the optically pumped Cs laser in a sealed-off cell. The study of the possibility of utilizing photodissociated TlBr as a gaseous laser medium was pursued. Crystalline and glassy media for rare-earth ions were studied. Oscillation has been achieved in prism cavities formed by a corner-cube reflector facing either a flat or another corner-cube. Results are presented of a study directed toward maximizing the overall efficiency and angular brightness of mechanically Q-switched ruby oscillators. Author

N63-14645 Army Missile Command. Physical Sciences Lab., Redstone Arsenal, Ala.

THE EXCITED STATE-LATTICE INTERACTION OF THE F-CENTER
R. A. Shatas Feb. 28, 1963 15 p 21 refs (RR-TR-63-1)

After an initial discussion of the importance of phonon processes in optical maser research, a brief survey of photon and phonon transitions occurring as a consequence of the optical excitation of the F-center is presented. The existence of metastable excited F-states is

postulated to account for a longer-than-predicted lifetime of the excited F-state. Infrared quenching, photoconductivity, and absorption modulation experiments are outlined for the purpose of testing the metastable state hypothesis. Author

N63-14737 Naval Research Lab. Washington, D C

NRL PROGRESS IN RADIO ASTRONOMY (1961-1962)
E F Mc Clain *In its* Report of NRL Progress Mar 1963 p 1-8 25 refs (See N63-14736 11-05) OTS: \$1 25

Recent progress in radio astronomy at NRL is reviewed. Important observational results have been obtained from studies of planetary radiation and from studies of the brightness and polarization of radio stars. Significant advances in instrumentation have included maser development and improved receiver sensitivity. Author

N63-14768 Aeronautical Systems Div. Physics Lab., Wright-Patterson AFB, Ohio

ANNOTATED BIBLIOGRAPHY ON SOLID STATE OPTICAL AND INFRARED MASER MATERIALS (A Summary of Abstracts from Current Literature up to Dec. 1961)
Dieter Feldmann Jan. 1963 38 p 107 refs (ASD-TDR-62-1026)

This report contains abstracts of approximately 110 articles from 25 different scientific journals. It covers theory and survey, solid state maser materials, maser optics, properties (coherence and others), related basic research, and organic, semiconducting, and gas masers. The survey includes articles from the beginning of the optical maser research to December 1961. Author

N63-14868 RAND Corp., Santa Monica, Calif.

THE INTERACTION OF LASER LIGHT WITH METALS (ELECTRON-OPTICAL PHONON INTERACTION IN METALS)
H. T. Yura Mar. 1963 38 p 7 refs (Contract AF 49(638)-700; Proj. RAND) (RM-3560-PR)

The interaction of laser light with a metal is studied. A model is proposed in which the dominant mechanism for electron de-excitation in transition metals is by the emission of optical phonons, as contrasted to the simple metals where the dominant mechanism is by the emission of acoustic phonons. Calculations based on this model give, for steel, an electron—optical phonon relaxation time $\sim 10^{-7}$ to 10^{-6} sec. compared with an electron—acoustic phonon relaxation time $\sim 10^{-11}$ to 10^{-10} sec. for a simple metal such as copper. Author

N63-15067 Air Force Cambridge Research Labs Electronics Research Directorate, Bedford, Mass

LASERS—A BASIC DISCUSSION OF TYPES, PROPERTIES, AND PRINCIPLES Research Note
C. Martin Stickley Jan 1963 29 p 6 refs (AFCLR-63-1)

This report describes the basic aspects of a laser. It includes a quantitative discussion of the major properties and the different types of lasers, as well as the basic laser mechanism—stimulated emission. Several applications are presented in order to illustrate the properties of the laser. Author

N63-15413 California U., Berkeley Electronics Research Lab
PHOTODISSOCIATION OF MOLECULES FOR EXCITATION OF AN OPTICAL MASER

J. R. Singer Jan 8, 1962 10 p 6 refs
(Contract AF 49(638)-102)
(IER Ser 60, Issue 429, AFOSR-2251)

A technique is proposed for the elimination of Doppler broadening in optical masers by observing atomic transitions perpendicular to the path of an atomic beam. The general plan is to photodissociate the molecules within an optically resonant structure, and have the excited atoms decay with the emission of coherent light because of the positive regeneration of the structure. Atom and ion emission data are summarized for materials which are candidates for a molecular-beam optical maser.

N63-15453 Massachusetts Inst. of Tech., Cambridge
**ISOTOPE SHIFT AND SATURATION BEHAVIOR OF THE
1.5 μ TRANSITION OF Ne**

A. Szoke (Weizman Inst.) and A. Javan Apr. 26, 1963 10 p 7 refs
Submitted for Publications

(NASA Grant NsG-330)
OTS: \$1.10 ph, \$0.80 mf

An experiment conducted with a helium-neon optical maser is summarized; the isotope effect, together with the saturation behavior of one of the Doppler-broadened optical transitions on Neon at 1.15 μ , is studied. A study of the maser's power dip when it is in a standing optical field gives information on the saturation behavior and the relaxation processes of the active atoms. The reproduction of the maser's optimum frequency then gives the index of the isotope effect and data on the saturation behavior. D. E. R.

N63-15737 Rochester U Inst of Optics, N.Y
**RADIOMETRIC CONSIDERATIONS IN CURVED MIRROR
GAS LASERS**

Douglas C. Sinclair Mar. 20, 1963 18 p 5 refs
(Grant DA-AROD(D)-31-124-G139)
(AROD-3309-2)

In most of the anticipated applications of the gas laser, the beam must be collimated so that only that fraction of the total radiant flux which can be put in a collimated beam will be of use. It is shown in this report that, for practical purposes, the amount of radiant flux that can be put in a collimated beam is limited by the flux available in the TEM₀₀ mode (Transverse Electromagnetic Mode), and that one cannot increase the radiant flux in a higher order mode. It would thus appear that, in applications which involve collimating the laser beam, it is desirable to operate the laser in the TEM₀₀ mode, since the additional radiant flux contained in the higher order modes is not useful. Author

N63-15802 Naval Ordnance Lab., White Oak, Md.
**SOLID STATE RESEARCH OF THE APPLIED PHYSICS
DEPARTMENT FOR THE YEAR 1961**

D. F. Bleil et al July 16, 1962 64 p 96 refs
(NOLTR-62-125)

Emphasis has been placed upon the optical and electrical properties of the lead salt semiconductors and work on the compound SnTe. Surface transport studies of semiconductors were clarified by a reformulation of the Boltzmann equation. Magnetoelastic interactions constituted an important effort during the year. Acoustic investigations of SiO₂ were continued with reference to the Si-O-Si bond that included the relationships between specific heat and temperature dependence of the elastic moduli of SiO₂ glass. Laser mechanisms have been studied by the use of high-speed photography. A new alloy, Nitinol, revealed many unusual properties. Certain device applications of solid-state principles are reported. Author

N63-16379 Gt. Brit. Ministry of Aviation. Technical Information and Library Services, Mottingham
**LASERS: A BIBLIOGRAPHY COVERING THE PERIOD
DECEMBER 1958-MAY 1962**

K. J. Spencer May 1962 41 p 409 refs
(Its Bibliographical Series No. 4)

An annotated bibliography on lasers is presented, covering the period December 1958 to May 1962. D.M.B.

N63-16449 Watkins-Johnson Co., Palo Alto, Calif.
**RESEARCH AND INVESTIGATION OF MATERIALS FOR
LASER APPLICATIONS Interim Engineering Report No. 3,
Jan. 1, 1963-Mar. 31, 1963**

R Fitzpatrick and S. E. Sobottka [1963] 18 p 2 refs
(Contract AF 33(657)-8917)
(W-J 63-612R12)

Light emission from pulsed diodes made of Nd doped GaAs and from undoped GaAs diode lasers was investigated. For the Nd doped diode studies, two different doped GaAs samples were used: One of a single crystal material containing an amount of Nd determined by independent analysis to be about 0.01 percent, and one of polycrystalline material containing about 0.7 percent Nd distributed in an unknown manner. Emission measurements of Nd doped diodes revealed lines in the range of 0.1 μ to 1.1 μ . These lines were not observed with five undoped GaAs diodes and were therefore indicated to be Nd emission lines. This is apparently the first time that emission from rare-earth ions has been reported. This emission indicates that the d.c. excitation of rare-earth centers in semiconductors is possible, as was originally predicted. Therefore the possibility of a low-threshold d.c.-pumped laser using rare-earth doped semiconductors seems assured. Also, diodes from GaAs without Nd have been fabricated according to techniques designed to optimize laser action. Studies of the emission of these diodes, integrated over all wavelengths, have been made as a function of current, up to 10 amps peak, with the diode immersed in liquid N₂. Results indicate that laser action occurs at peak currents above a few amps (current density about 10³ amp/cm²). I.v.L.

N63 16686 California Inst of Tech Quantum Electronics
Lab Pasadena
**MULTI-REFLECTOR OPTICAL RESONATORS Scientific Re-
port No 3**

Peter O Clark Apr 10, 1963 8 p 9 refs
(Contract AF 19(604) 8052)
(AFCLR 63 115)

An analysis of multireflector optical resonators based on geometrical optics is presented, and the conditions for stable operation of these devices are determined. A four-mirror system which uses spherical reflectors 1 and 1' with a radius of curvature b₁ and reflectors 2 and 2' with radius of curvature b₂ is considered. The geometrical optics of such a system are treated in a manner similar to that of Pierce (1954) and Boyd and Kogelnik (1962). The symmetry of the resonator allows the path of a ray to be described by four difference equations whose approximate solution leads directly to a linear, homogeneous difference equation for the stability condition. The reductions of this stability equation for the rhomboidal resonator and for the rectangular resonator are presented. This analysis is applicable to optical masers with four-mirror cavities, ring lasers, and mode selection in toroidal ruby lasers. M.P.G.

N63-17336 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena
RADIO AND OPTICAL SPACE COMMUNICATIONS

R. D. Potter, R. Stevens, and W. H. Wells Oct 30, 1962 22 p 38 refs Presented at the Sixth Meeting of the AGARD Avionics Panel, Paris, July 6-12, 1962
(NASA Contract NAS7-100)

(NASA-CR-50062 JPL-TM-33-85) OTS: \$2.60 ph, \$0.86 mf

The theory and state-of-the-art of laser sources is reviewed, with the possible application of these devices to space communications and long-range radar (or lidar). Sample optical and radio-frequency systems are analyzed in detail. Practical system and component problems which arise in optical communication and lidar systems are discussed. Author

N63-17397 Aerospace Information Div., Library of Congress, Washington, D C

STIMULATED EMISSION FROM ORGANIC MOLECULES WITH POSSIBLE LASER APPLICATIONS Review Article
June 17, 1963 7 p

(AID-P-63-85) OTS \$1 10 ph. \$0.80 mf

A general outline is presented of U.S.S.R. papers on organic materials for Soviet lasers and the type of work being done in the U.S.S.R. in the laser field. N.E.A.

N63-17908 Army Electronics Research and Development Lab., Fort Monmouth, N.J.

INFLUENCE OF A D.C. AND A.C. MAGNETIC FIELD UPON A GAS DISCHARGE LASER

Rudolf G. Buser, Johann J. Kainz, and John J. Sullivan Dec. 1962 22 p 10 refs
(USAE/RDL-TR-2322)

The influence of a magnetic field upon a gas discharge laser has been investigated. The magnetic field changes the spatial and energy distribution of the electrons, and therefore influences the light output of the laser. Experiments show that this effect may be useful for adjustment and modulation of the laser emission. Author

N63-18111 Ohio State U. Research Foundation, Antenna Lab., Columbus

A LIQUID CALORIMETER FOR LASER ENERGY

James T. Flynn (M.S. Thesis) Nov. 15, 1962 57 p 10 refs
(Contract AF 33(616)-7081)
(Rept. 1083-18)

A liquid absorption calorimeter for laser energy has been designed and tested. Its primary advantage over carbon or metal calorimeters is the absorption of the incident energy throughout a volume rather than on a surface, thus limiting the initial temperature rise to a few degrees. Two models have been built, and tested with pulsed ruby lasers; both use thermistor-bridge temperature sensors. No compensation of the bridge for ambient temperature variation is attempted, but final calibration curves include this variation. Measurements with accuracy of 10% are possible up to pulse energies of 10 joules, with a 40- to 60-second interval between measurements. The upper energy limit can be increased to any desired value by increasing the volume of the absorption cell, at the cost of a longer recovery time. Measurements of laser output versus pumping energy, and of laser output versus transmissivity of silver and gold end-films are shown. Author

N63-18148 American Optical Co., Southbridge, Mass
NEODYMIUM GLASS LASER

Elias Snitzer 1962 23 p 8 refs Presented at the Third Intern Symp on Quantum Electronics Paris, Feb 1963
(Contract DA 19 020-ORD 5575)
(AROD-3209 2)

The properties of the neodymium glass laser in high power and in fiber configurations are discussed. The results are presented of recent experiments on spectral pumping efficiency, output as a function of time, influence of the glass base containing the neodymium, and spectral output. Author

N63-18287 Ohio State U. Research Foundation, Antenna Lab., Columbus

WATER VAPOR ABSORPTION STUDIES WITH A HELIUM-NEON OPTICAL MASER

Ronald K. Long and Thomas H. Lewis Nov. 30, 1962 22 p 8 refs

(Contract AF 33(616)-7081)
(Rept. 1083-20)

Propagation characteristics of various lasers for potential application in communications are evaluated. Data are obtained from experimental measurements of the percent absorption of the 11522.82 Å laser radiation by water vapor and water-vapor-nitrogen mixtures as a function of pressure. Absorption at 6328 Å is also discussed and compared to absorption at 11523 Å. The experimental results showed that, in some respects, 6328 Å would be superior to 11523 Å for communications. However, data have been presented to enable the design of system at 11523 Å if other factors lead to this choice. Because of the λ^4 wavelength dependence, for example, the IR wavelength would be superior to the visible as far as scattering is concerned. At optical wavelengths, the ultimate channel capacity may be limited by the number of photons/second available from the source. This, too, would favor a longer wave length. N.E.A.

N63-18288 Ohio State U. Research Foundation, Antenna Lab., Columbus

IONIZATION OF GASES BY OPTICAL MASER RADIATION

E. K. Damon and R. G. Tomlinson Nov. 30, 1962 9 p refs
(Contract AF 33(616)-7081)

(Rept. 1083-19)

Apparent ionization of noble and atmospheric gases in a focused laser beam has been observed. The effect shows a strong nonlinearity and appears to be power dependent rather than energy dependent. The results of preliminary measurements using conventional and Q-switched laser pulses are included. Author

N63-18672 Technical Research Group, Syosset, N.Y.
RESEARCH ON PROPERTIES OF LASER DEVICES Fourth

Quarterly Technical Summary Report, Mar. 1963-May 1963

M. Newstein and S. Rothberg, eds. [1963] 153 p 74 refs
(Contract AF 49(638)-673; ARPA Order 356-62; Proj. Defender)

(TRG-134-QTR-4)

Theoretical study of the performance of pulse oscillators was continued. Qualitative agreement was obtained with results of experiments dealing with the effects of varying cavity time constant and scattering loss. Crystalline and glassy media for rare-earth ions were studied. Work on laser pumping by the photodissociation of molecules was continued, and extended to include CsBr and CsI in addition to TlBr. Work on the metastable transition laser was begun. The noise power spectrum of a laser was investigated. Oscillation was achieved in more lasers with retroreflecting prism cavities, and their properties investigated. The study of Q-switched lasers was continued, and a new faster mechanical Q-switch was designed. Author

N63-18709 Utah U. Microwave Devices Lab., Salt Lake City
IRRADIATED LASER MATERIALS

V. R. Johnson and R. W. Grow *In its* Microwave Devices Lab. Consolidated Quarterly Rept. Mar. 31, 1963 p 42-44 (See N63-18701 17-09)

(NSF Grant 15017)

Progress is reported on a project designed to investigate the possibility of reducing the pumping energy required for a

solid-state ruby laser by γ -ray damage and by applying extremely high static pressure. A nitrogen-cooled ruby rod in elliptical laser cavity apparatus was constructed and tried. The apparatus proved unsuccessful. The rod was next γ -irradiated at room temperature for periods of the order of 15 to 25 hours. This amount of irradiation was sufficient to snuff out laser action in the crystal, at least for the input pump power available. The γ -damage in ruby was found to be annealed out by heating the crystal to about 400°C and at least partially annealed by optically pumping the crystal in a laser configuration. N.E.A.

N63-18711 Utah U. Microwave Devices Lab., Salt Lake City
MILLIMETER WAVE MASERS

J. C. Clark and R. W. Grow *In its* Microwave Devices Lab. Consolidated Quarterly Rept. Mar. 31, 1963 p 48-50 4 refs (See N63-18701 17-09)
(NSF Grant 15017)

Materials suitable for use in solid-state masers at millimeter wavelength are investigated. The primary activity of the report period consisted of literature search of both the current research concerned with millimeter wave maser materials and fundamental background information applicable for these cases. Both Eu^{++} in CaF and SrCl have been suggested as materials that may have an allowed microwave transition that can be inverted near one of the levels of the optical transition. One other type of material that is potentially worth consideration for use in the millimeter wavelength region is a solid-state maser using the cyclotron resonance levels and impurity doping levels in semiconductors. N.E.A.

N63-18911 General Electric Co. Advanced Semiconductor Lab., Syracuse, N.Y.

SEMICONDUCTOR DEVICE CONCEPTS Scientific Report No. 3B

N. Holonyak Feb. 28, 1963 19 p 9 refs
(Contract AF 19(628)-329)
(AFCRRL-63-120(B))

A status report on the preparation and properties of $\text{Ga}(\text{As}_{1-x}\text{P}_x)$ p-n junction lasers is presented. Halogen vapor transport synthesis of $\text{Ga}(\text{As}_{1-x}\text{P}_x)$ and its preparation into laser junctions are described. Electrical and optical properties of $\text{Ga}(\text{As}_{1-x}\text{P}_x)$ laser junctions are discussed. The present limitations in these properties are related to material problems and the very early state of development of $\text{Ga}(\text{As}_{1-x}\text{P}_x)$, and are discussed in this context. Author

N63-19140 Cornell U. School of Electrical Engineering, Ithaca

INVESTIGATION OF NEW CONCEPTS FOR MICROWAVE POWER GENERATION [Third Quarterly Progress Report, Jan. 1-Mar. 31, 1963]

L. F. Eastman and L. A. Mac Kenzie Griffiss AFB, N.Y., Techniques Lab., June 1963 58 p 2 refs
(Contract AF 30(602)-2833)
(RADC-TDR-63-219; EE-560)

Experimental work reported includes the design and construction of the vacuum system, measurements of the magnetic field along the system axis, and the design and construction of a demountable plasma chamber. This chamber has cathodes for a hot-cathode Penning discharge, input and output cavities, and will allow ready variation of a gas pressure. A pulsed laser system utilizing a ruby crystal has been constructed to investigate the feasibility of obtaining very dense thermionic emission from a metallic cathode when it is surface heated by a pulsed laser beam. The problem of end coatings

on the crystal with a suitable lifetime has been solved, and a new optical aligning technique has been developed for aligning and focusing the laser beam onto the cathode surface. The first few emission tests used a test diode utilizing a tungsten wire cathode, which gave a "plasma jet," or gaseous tungsten discharge current from the cathode at low pressures. When a negative bias was applied to the diode, large peak ion currents were observed. When the laser output energy was sufficiently reduced, the first traces of thermionic emission current were obtained. Author

N63-19405 California U., Berkeley
Electronics Research Lab

INTENSITY MEASUREMENTS FOR OPTICAL MASER APPLICATIONS

W F Kolbe Apr 22, 1963 23 p 12 refs
(Grant DA-ARO(D)-31-124-G151)
(AROD-3323-2)

The experimental determination of absolute intensities of visible and near-visible light sources is considered. A photoelectric method was used, incorporating a Jarrell-Ash 34-meter Ebert Spectrograph and a tungsten strip filament lamp as a standard source. Calibration curves covering the spectrum from 3500 to 11,000 Angstroms were obtained, relating the source brightness $B(\lambda)$ to the photomultiplier current $I(\lambda)$ for the spectrograph used. The preliminary measurements made indicate that the method is reasonably accurate in determining the relative intensities of various spectral lines of a given source, but only moderately successful in determining absolute intensities. Some methods for improving the latter are considered. Author

N63-19444 Lockheed Missiles and Space Co., Sunnyvale, Calif

METALWORKING APPLICATIONS OF LASERS: AN ANNOTATED BIBLIOGRAPHY

Helen B. Mc Cormick comp. Feb. 1963 30 p 66 refs
(Rept. 5-73-63 5; SB-63-22)

Applications of lasers in metalworking are reported here, with excerpts, summaries, and quotations pointing out the most relevant information in the items reviewed. Metal working applications include welding, machining, piercing and drilling, melting and vaporizing, fabrication of refractory materials, and the microwelding and micromachining of fragile components and interconnections for electronics and optical communications uses. Measuring and gaging applications, high-speed photography, and high-temperature testing of materials characteristics are other likely applications mentioned. References are made also to safety precautions for laser use, and to components and equipment now available for experimental or shop use. Author

N63-19641 Cornell Aeronautical Lab., Inc., Buffalo, N.Y.
THE POSSIBLE PRODUCTION OF POPULATION INVERSIONS BY GASEDYNAMIC METHODS

Ian R. Hurler, A. Hertzberg, and John D. Buckmaster Dec. 1962 22 p 9 refs
(CAL-RH-1670-A-1)

The possible production of large population inversions in electronic states by techniques involving fast expansion of a thermally excited gas is discussed. The inversion is obtained through the rapid radiative de-excitation of the lower electronic state of a suitable atom during the expansion process. The extent of the inversion produced in a particularly convenient type of expansion is examined, and the feasibility of subsequent laser action is considered. Author

N63-19987 Ohio State U. Research Foundation, Columbus
Antenna Lab
ABSORPTION OF LASER RADIATION IN THE ATMOSPHERE
Ronald K. Long May 31, 1963 167 p 64 refs
(Contract AF 33(657)-10824)
(Rept 1579-3)

Laser sources have been proposed for communications and radar applications in the atmosphere; therefore, a knowledge of the loss parameters of the atmosphere at the laser frequencies is needed for the design of these systems. This work presents a study of one of these loss parameters, molecular resonance absorption, over the 0.6- to 20.0-micron wavelength region. The absorption at more than one hundred laser frequencies was determined. A multiple traversal absorption-cell system is described which is capable of making absorption measurements with path lengths of up to one mile, and at pressures simulating atmospheric conditions from sea level to eighty-miles altitude. Measurements made with the absorption cell and a 11522.76 Angstrom helium-neon laser are described. A study of the absorption by oxygen and water vapor in the 6934 to 6944 Angstrom ruby wavelength region was made using a high resolution solar spectrograph and also using a room temperature laser and the laboratory absorption cell
Author

N63-20033 Columbia U., New York, N.Y.
Radiation Lab
RESEARCH INVESTIGATION DIRECTED TOWARD EXTENDING THE USEFUL RANGE OF THE ELECTROMAGNETIC SPECTRUM Second Quarterly Progress Report, Mar. 16 through June 15, 1963
R Novick June 15, 1963 71 p refs
(Contract DA-36-039-SC-90789)
(CU-6-63-SC-90789)

The nuclear spin and magnetic moment of ^{115}Cd have been determined by optical double resonance. Positive identification of the isotope was obtained by the observation of the decay of the resonances. The atomic g factor for the $(5s5p)^3P_1$ state of Cd has been determined to 10 ppm with a K-band optical double-resonance spectrometer. Metastable autoionizing states have been discovered in potassium and rubidium, and it has been shown that these can be quenched with an electric field (Stark quenching). The hyperfine structure of the $(4s4p)^3P_1$ state of Zn^{67} has been redetermined. Level crossings have been detected in the $(3d)^54p$ and $(3d)^44s4p$ configurations of chromium; the lifetimes of these states were determined from the widths of the crossing resonances. The spin-lattice relaxation rate for He^3 nuclei in solid He^3 has been calculated and the results compare favorably with experiment. A new, low temperature, Q-switched ruby laser has been constructed as the excitation source for a photon echo experiment. A cryostat for the ENDOR spectrometer, which permits the sample to be cooled to liquid hydrogen temperature, has been built and operated successfully. The hyperfine interaction of the Ag^+ center in KCl with the neighboring chlorine ions has been resolved by the ENDOR technique at liquid hydrogen temperatures. A new laser spectrometer has been constructed and tested. This is to be used for the study of photon phonon interactions in liquids and solids. A sensitive high-pressure microwave absorption spectrometer has been constructed and used for the study of the absorption in CO_2 . Detailed study of the microwave absorption of various gases present in planetary atmospheres is required for the full interpretation of the results that have been obtained by interplanetary radar.
Author

N63-20348 General Electric Co., Schenectady, N.Y. Research Lab
THE LASER
J. D. Kingsley Apr 1963 10 p 8 refs
(Rept 63-RL-3306-G)

An elementary, qualitative discussion of the laser is given, including a description of stimulated emission. Several fundamental means of achieving a population inversion are discussed as well as the basic form of a laser. The areas in which lasers may be applied are discussed briefly and in very general terms.
Author

N63-20413 California U., Berkeley Electronics Research Lab.
THREE-LEVEL MASER MATERIALS: A SURVEY OF POTENTIAL MATERIALS, II
J. Wakabayashi June 1, 1962 112 p 80 refs
(Contract AF 49(638)-102)
(IER Ser. 60, Issue 452)

Paramagnetic resonance of impurities in natural crystals of calcite (CaCO_3) and barite (BaSO_4) was investigated. Observed spectra are compared with the theoretical spectra of probable impurities. One spectrum in calcite is identified with Fe^{3+} . Another is possibly due to Cr^{3+} . No identifiable spectrum was observed in barite.
Author

N63-20472 Michigan U. Inst. of Science and Tech., Ann Arbor Solid-State Phys. Lab.
THE ABSORPTION AND EMISSION SPECTRUM OF $\text{CaF}_2:\text{U}^{+++}$
Robert E. Meredith and Joe A. Jenney Aug 1963 16 p 6 refs
(Contract DA-36-039-SC-78801; Proj. Michigan)
(Rept. 2900-438-R)

The emission and absorption of $\text{CaF}_2:\text{U}^{+++}$ have been scanned at 77°K and 4.2°K , and line widths have been measured. The spectrum is interpreted as arising from ions perturbed by a weak tetragonal crystal field. Preliminary results of the Zeeman effect on the narrowest lines are presented.
Author

N63-20668 Aerospace Corp., El Segundo, Calif.
DISLOCATIONS IN RUBY LASER CRYSTALS
K. Janowski and H. Conrad July 29, 1963 34 p 10 refs
(Contract AF 04(695)-169)
(TDR-169(3240-01)TN-2; SSD-TDR-63-172)

A detailed study was made of the dislocation structure of ruby crystals obtained from various sources. Using KHSO_4 as an etchant, a detailed mapping of the dislocation structure on the $(000\bar{1})$ and the $(11\bar{2}0)$ planes was performed. A less extensive study was made of the rhombohedral planes. The average dislocation density on the basal plane was 1.5 to $3 \times 10^6 \text{cm}^{-2}$, and on the $(11\bar{2}0)$ planes it was approximately $5 \times 10^5 \text{cm}^{-2}$. However, considerable variation existed between areas on a given plane. The subboundaries in the basal plane tended to lie along $[1\bar{1}00]$ type directions while those on the $(11\bar{2}0)$ plane tended to lie: (a) parallel to the basal plane, (b) along traces of the $(1\bar{1}01)$ plane, and (c) along normals to the traces of the (0001) planes. These orientations suggest that many of the dislocations lie on the (0001) , $\{1\bar{1}01\}$ and $\{11\bar{2}0\}$ planes.
Author

N63-20995 Royal Aircraft Establishment, Farnborough (Gt Brit)
THE OPTICAL MASER [DER OPTISCHE MASER]
W. Kaiser London, Ministry of Aviation May 1963 33 p 79 refs In ENGLISH Transl from Phys Stat Sol 2, 1962 p 1117-1143
(RAE Lib Transl 1037)

* A review of the present knowledge of the optical maser has been carried out. The maser condition for certain resonant bodies is described, and a brief account of the kinetics of the solid-state maser is given. Recent work on the gas maser is reported, and the essential properties of the radiation of the solid-state maser and the gas maser are discussed. Some applications of optical masers are mentioned. Author

N63-21026 Joint Publications Research Service, Washington, D.C.

QUANTUM GENERATORS AND "DEATH RAYS"

P. T. Astashenkov Sept. 6, 1963 16 p Transl. into ENGLISH of an article from *Ast. Radiotekhn.*, Moscow, 1962 p 77-89 (JPRS-20959; OTS-63-31696) OTS: \$0.50

A discussion is presented on the creation of monochromatic light sources which make it possible to obtain beams of radiation which are as sharply directed as needles, and to generate temperature effects equal to 10^{10} °C. These particular characteristics are discussed in terms of developing methods and instruments for local and space communication systems, space navigation, location and range finders, and for producing death rays which are to be used in a defense system against missile attack. C.L.W.

N63-21469 Army Missile Command, Huntsville, Ala. Physical Sciences Lab.

RADIATION DAMAGE BY COMPTON SCATTERING IN GAMMA OR X-RAY PUMPED OPTICAL MASERS

R. A. Shates Apr. 15, 1963 15 p 5 refs (RR-TN-63-2)

The computation of threshold energies of X-rays and gamma rays for the displacement of a lattice element by the nuclear Compton scattering is reported. Numerical results are given for alkali halides and oxides. These computations were carried out as a part of a general feasibility study of direct pumping of optical masers by radiations emitted in the nuclear fission of transactinides. Based on the analysis of the fission data for U^{235} , it is concluded that the direct pumping is not yet technologically feasible because: (1) only a small fraction of the total energy released by the nuclear fission can presently be made available in X-rays and gammas, (2) serious radiation damage to the optical maser material would occur if fast neutrons or high-energy gammas were used in pumping. As an alternate, the conventional conversion of fission energy into electricity and the electrical pumping by carrier injection into recombination radiation devices is suggested. Author

N63-22216 Picatinny Arsenal, Dover, N.J.

AN INVESTIGATION INTO THE FEASIBILITY OF A PYROTECHNIC LASER PUMP

Chester L. Smith and Paul J. Kisatsky Aug. 1963 63 p (PA-TR-3102)

Pyrotechnic compositions consisting of two basic ingredients—fuels and oxidizers—were tested in various combinations. Combinations of pyrotechnic ingredients and high explosives were also examined, and high explosives in various configurations were tested. Brightness tests on the above combinations were conducted with various means of containing and confining the materials. A squib of $Zr/KClO_4$ emerged as the brightest emitter. The brightness was enhanced by use of a particular fixture. (This laser pump fixture utilized distributed pyrotechnics on the printed-bridge wire matrix.) The ingredients of the $Zr/KClO_4$ were varied from

stoichiometric to a fuel-rich combination, with the stoichiometric ratio giving the highest output on the brightness bench. The temperature reached, with the combination, was 4900°K. The brisance of the explosive and pyrotechnic composition was high, and would, therefore, pose a severe problem when trying to avoid damage of the laser crystal. Consequently, it has been decided to work with a pyrotechnic composition, $Zr/KClO_4$ in particular, in a standard squib body rather than with an explosive and pyrotechnic composition. I.v.L.

N63-22258 Services Electronics Research Lab., Baldock (Gt. Brit.)

THE ONSET OF STIMULATED EMISSION FROM GaAs SEMICONDUCTOR OPTICAL MASERS

R. F. Broom, C. H. Gooch, C. Hilsom, and D. J. Oliver In *SERL Tech. Journal*, June 1963 p 90-92 2 refs Submitted for publication (See N63-22251 23-01)

The fabrication of gallium arsenide junction diodes, which show signs of coherent emission at current densities as low as 1,500 amps/cm² at a diode temperature of about 100°K, is reported. These values are considerably lower than any previously reported. The explanation given is that, in the particular regions of the diode at which coherent spectral emission was observed, the impurity level, the defect concentration, and the abruptness of the transition region are nearer the optimum for efficient conversion of electrical current into infrared radiation, so that these regions emit coherent radiation at lower current densities than the rest of the junction. M.P.G.

N63-22774 Space Technology Labs., Inc., Redondo Beach, Calif.

MASERS AND LASERS: A BIBLIOGRAPHY 1962 Supplement

J. F. Price and A. K. Dunlap Mar. 1963 182 p 1134 refs Suppl. to N62-16763 17-21 (Research Bibliography 45; Rept. 9990-6369-KU2000)

This bibliography consists of 1134 references on masers and lasers. The majority of the references are those published in 1962 as well as those released in 1962 by ASTIA and NASA. This bibliography is a supplement to NASA N62-16763. J.E.T.

N63-22877 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena

DUAL-CAVITY MASER USED IN MARS RADAR EXPERIMENT

W. H. Higa and R. C. Clauss June 1963 2 p 3 refs Repr. from *IEEE Proc.*, v. 51, no. 6, June 1963 (NASA Contract NAS7-100) (NASA CR-52020; JPL Tech. Rept. 32-432)

A dual-cavity ruby maser was used in a radar experiment in which echoes were received from Mars. A Cassegrainian antenna configuration made it possible to achieve a total system temperature of around 40°K. The detected signal level of the Mars echo was of the order of -180 dbm. The principal advantage of the multiple-cavity maser is the improved gain stability over a single-cavity unit operating with the same total gain. A diagram of the microwave circuit for the dual-cavity maser and a cross-sectional view of one of two identical maser units are given. C.L.W.

N63-23167 California U., Berkeley Electronics Research Lab

DIOMIC GAS OPTICAL MASER WITH EXPLODING WIRE PUMPING SOURCE

L. Hajdu June 5, 1963 41 p 23 refs
(Grant DA-ARO(D)-31-124-G317; Contract AF 49(638)-102)
(Rept 63-12, AROD-33233)

The feasibility of a gaseous maser in which the excited atoms are produced through photochemical decomposition of diatomic molecules (such as N_2 , O_2 , and NO) is studied. As an example, the photodissociation of NO is discussed in detail. Because of the required high excitation energies, the useful pumping band of such a system is in the extreme ultraviolet. Exploding wire is suggested as a suitable light source, having very intense output in the vacuum ultraviolet, with excellent reproducibility of its spectral characteristics per flash. Preliminary experiments show that when N_2 and O_2 molecules are photoactivated by the light output of an exploding wire, the 7468 Å nitrogen and 8446 Å oxygen emission lines appear with relatively high intensities

Author

N63-23304 Air Force Cambridge Research Labs., Bedford, Mass

LARGOS: A SUGGESTED METHOD FOR STEREO-TRIANGULATION

Michael S. Tavenner *In its* Compendium of Papers in the Fields of Geodesy and Planetary Geometry Aug 1963 9 p refs Presented at the 43rd Ann. Meeting, Amer. Geophys. Union, Washington, Apr. 1962 (See N63-23301 24-01)

Lasers, located at each ground observing station, beam light pulses activated by a common triggering circuit to the satellite. The satellite reflects each signal to its respective source where the signal is recorded on a photographic plate against a background of stars. Reduction of these photographic plates gives extremely accurate information as to satellite and/or ground station position. Advantages of LARGOS are: (1) All complicated equipment is on the ground where it may be repaired or adjusted; (2) by keeping prismatic reflectors small, weight is held to a minimum; (3) power requirements for the source are small ($\approx 10^3$ watt seconds); (4) the system is adaptable for tracking any satellite or missile.

Author

N63-23312 Air Force Cambridge Research Labs., Bedford, Mass.

GEODETTIC APPLICATIONS OF LASERS

Paul B. Swenson *In its* Compendium of Papers in the Fields of Geodesy and Planetary Geometry Aug. 1963 4 p Presented to the Geodetic Planning Factors Conf., Orlando AFB, Dec. 1962 (See N63-23301 24-01)

Two uses of lasers in geodetics are discussed. In the first, a laser pulse would be directed at a satellite which carries a prismatic or retrodirective reflector. The reflected beam would be photographed by stellar cameras as a point source in the reference star background, and then the plates would be handled like any other geodetic stellar plate. In the second, a laser pulse would be used to measure accurately the relative heights of the surface features of the moon. This would be accomplished by beaming a very short laser pulse to the moon and measuring its transit time out and back

P.V.E.

N63-23343 Avco-Everett Research Lab., Everett, Mass.
POPULATION INVERSION BETWEEN BOUND AND REPULSIVE MOLECULAR ELECTRONIC STATES BY TWO-TEMPERATURE EQUILIBRIUM

D. A. Leonard, J. C. Keck and M. M. Litvak (M.I.T.) Aug. 1963 9 p 4 refs

(Contract AF 04(694)-33)

(Avco-Everett Res. Rept.-164; BSD-TDR-63-170)

The well-known ultraviolet-emission continuum of molecular hydrogen which results from transitions between the $a^3\Sigma_g^+$ and $b^3\Sigma_u^+$ electronic states is suggested as a transition for a high-power, ultraviolet, gas laser. In an electric arc, collisions of hot electrons with ground state molecules populate these two states. Steady-state inversion can be achieved by maintaining the heavy particle temperature below the electron temperature, and by maintaining the hydrogen atom concentration below the equilibrium value corresponding to the electron temperature. This suppresses the population of the lower state by reducing the rate of recombination of ground state atoms into the repulsive state. A two-temperature quasi-equilibrium model requires a temperature ratio of 1.5 for inversion.

Author

N63-23467 Florence U. (Italy) Istituto di Fisica della Radiazione

RESEARCH ON LASER [RICERCHE SUL LASER]

G. Toraldo di Francia *In* 1st Superiore di Sanita. Rome. The Seminar at the Physics Lab. during the Period Jan-Apr. 1963 Part II p 74-88 *In* ITALIAN (See N63-23465 24-23)

Laser research and possible laser applications are discussed
Trans. by P.F.E.

N63-23526 Bell Telephone Labs., Inc., Murray Hill, N.J.
SOLID-STATE MASER RESEARCH Final Report, 20 June 1962-19 June 1963

H. E. D. Scovil June 19, 1963 73 p refs
(Contract DA-36-039-sc-89169)

CONTENTS:

1. THE FILLING FACTOR OF THE TRAVELING-WAVE MASER W. J. Tabor p 9-16 refs (See N63-23527 24-25)
2. THE ISOLATOR INCORPORATED IN THE TRAVELING-WAVE MASER F. S. Chen p 16-25 refs
3. PART V—MASER PROPERTIES OF Cr^{+++} IN $ZnWO_4$ AT L-BAND W. G. Nilsen p 26-40 refs (See N63-23528 24-25)
4. PART VI—A GENERAL THEORY OF CROSS RELAXATION W. J. C. Grant p 41-62 refs (See N63-23529 24-25)

N63-23527 Bell Telephone Lab., Inc., Murray Hill, N.J.
THE FILLING FACTOR OF THE TRAVELING-WAVE MASER W. J. Tabor *In its* Solid-State Maser Res. June 19, 1963 p 9-16 refs (See N63-23526 24-25)

The filling factor for a traveling-wave maser (TWM) loaded only on one side is determined. Using a filling factor previously determined for a TWM completely filled with active material, the advantage or disadvantage of loading a maser on both sides of the comb or on only one side is discussed. An increase in electronic gain at midband is shown when the second side of the comb is filled with ruby, and 10 Gc a 30-percent increase in gain can be obtained by loading the second side with ruby. It is concluded that two-sided loading is more efficient at least up to X-band, although not by a very large margin.

P.V.E.

N63-23528 Bell Telephone Labs., Inc., Murray Hill, N.J.
MASER PROPERTIES OF Cr^{+++} IN $ZnWO_4$ AT L-BAND W. G. Nilsen *In its* Solid-State Maser Res. June 19, 1963 p 26-40 refs (See N63-23526 24-25)

The suitability of this material for L-band masers was studied and was found to give a gain (db)-bandwidth product superior to that of ruby maser material. However, the operating conditions for the maser material, i.e., temperature, frequency, and magnetic field make it impossible to find a companion isolator material for the design of traveling-wave masers.

Author

N63-23529 Bell Telephone Labs., Inc., Murray Hill, N.J.
A GENERAL THEORY OF CROSS RELAXATION
W. J. C. Grant *In its* Solid-State Maser Res. June 19, 1963
p 41-62 refs (See N63-23526 24-25)

A critical examination of existing theories of cross relaxation revealed room for an improved, more rigorous treatment. This theory of cross relaxation was developed for single spin flips, and subsequently extended for multiple spin flips. The theory was used to explain pertinent experimental observations.

Author

N63-23544 Hughes Research Labs., Malibu, Calif.
LASER DEVICES EXPLORATORY INVESTIGATION Interim Scientific Report No. 1, 1 May 1963-31 July 1963

[1963] 54 p refs
(Contract AF 33(657)-11650)

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- 1 SINGLE MODE CW INVESTIGATION p 3-7 refs
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V. Evtuhov and J. K. Neeland p 30-41 11 refs (See N63-23545 24-25)
- 5 APPENDIX II--MEASUREMENT OF RAMAN SCATTERING CROSS SECTIONS FOR USE IN CALCULATING STIMULATED RAMAN SCATTERING EFFECTS
F. J. Mc Clung and D. Weiner p 42-49 6 refs (See N63-23546 24-25)

N63-23545 Hughes Research Labs., Malibu, Calif.
CHARACTERISTICS OF RUBY LASER MODES IN A NOMINALLY PLANE PARALLEL RESONATOR
V. Evtuhov and J. K. Neeland *In its* Laser Devices Exploratory Invest. [1963] p 30-41 11 refs Submitted for Publication (See N63-23544 24-25)

Characteristics of ruby-laser modes in a nominally plane-parallel resonator were investigated. Results indicate that: (1) The modes observed in ruby lasers are those of a resonator with curved, but not necessarily spherical, end plates. (2) Most ruby lasers operate in such modes or a superposition of them rather than in the modes of a truly plane-parallel resonator. (3) Laser action is likely to start in areas of greatest effective end-plate curvature, in the case of rubies of large cross-sectional area, since the modes in such areas have the lowest losses. (4) The laser output, in the far field, consists of a center spot which results from superposition and interference of excited modes and Fabry-Perot rings, which are believed to be basically unrelated to the true modes.

I. v. L.

N63-23546 Hughes Research Labs., Malibu, Calif.
MEASUREMENT OF RAMAN SCATTERING CROSS SECTIONS FOR USE IN CALCULATING STIMULATED RAMAN SCATTERING EFFECTS

F. J. Mc Clung and D. Weiner *In its* Laser Devices Exploratory Invest. [1963] p 42-49 6 refs Submitted for Publication (See N63-23544 24-25)

The magnitude of stimulated Raman scattering (SRS), of the Raman laser effect, depends upon the peak values of ordinary Raman scattering cross sections, just as ordinary laser gain depends upon the peak value of an absorption cross section. Results are given of the first measurements of peak Raman scattering cross section for three Raman lines in nitrobenzene, benzene, and toluene for which SRS has been studied, and for two other lines, in benzene and toluene, from which no SRS could be produced within certain experimental limits. The characteristics of SRS as calculated from these cross sections agree with SRS threshold measurements for these substances. A ruby laser was used as the light source in the Raman spectrometer. Photometric detection was used with a 2-m grating spectrograph as the dispersing element.

Author

N63-23550 Linde Co., East Chicago, Ind.
RUBY IMPROVEMENT FOR LASER - TASK I Final Report, No. 4, May 1, 1962-May 31, 1963

R. L. Hutcheson [1963] 33 p
(Contract DA 36-039-SC-98089)

The effect of thermal gradients, growth rate, annealing cycle, fluxing agents, and orientation on the growth of ruby via the flame-fusion crystal growth is discussed. Data on crystals grown under the best selected parameters are presented.

Author

1964 STAR ENTRIES

N64-10108* National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Md.
THE S-66 LASER SATELLITE TRACKING EXPERIMENT
Henry H. Plotkin Feb. 13, 1963 24 p refs Presented at 3rd Intern. Conf. on Quantum Electron., Paris, Feb. 13, 1963 (NASA TM X-52075; NASA-X-524-63-59) OTS: \$2.60 ph, \$0.92 mf

The optical tracking experiment to be conducted with the S-66 satellite, the polar ionospheric beacon, is described. The plan consists of illuminating a special satellite-borne reflector with a pulse from a laser and receiving the reflected light on a tracking telescope, which transmits the data to a digital computer. Experiments have shown that this type of optical tracking is feasible, and that the readout of such a system can be expected to be accurate to 5 seconds of arc under the accelerations expected from satellites.

D. E. R.

N64-11088* National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Md.
MASERS FOR THE TELSTAR SATELLITE COMMUNICATIONS EXPERIMENT
W. J. Tabor and J. T. Sibia *In its* Telstar I, Vol. 3, Jun. 1963 p 1863-i886 refs (See N64-11079 02-01)

This paper discusses the design and characteristics of ruby traveling-wave masers operating at 4 Gc. These masers, characterized by an average gain of ≈ 35 db over a bandwidth of 25 Mc, are equipped with waveguide input transmission lines, rather than the previously employed coaxial cables. This change results in an overall noise temperature of 3.5° K for these devices, rather than the 10° K exhibited by earlier masers. The maser noise temperature now closely approximates sky

temperatures, which set the ultimate limit on earthbound receiver sensitivity. The improvements to be had by further reduction in amplifier noise are therefore almost negligible. A less well known maser property, i.e., its freedom from distortion, even when driven well into gain saturation, is discussed
Author

N64-11089* National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Md.

4-gc PARAMETRIC AMPLIFIER FOR SATELLITE COMMUNICATION GROUND STATION RECEIVER

M. Uenohara, M. Chrunev, K. M. Eisele, D. C. Hanson, and A. L. Stillwell *In its Telstar I*, Vol. 3 Jun. 1963 p 1887-1908 refs (See N64-11079 02-01)

The amplifier consists of two cascaded stages of similar design: the first of these is operated at liquid-nitrogen temperature and the second at room temperature. One 23-Gc pump source is used for both amplifier stages. The combination of the two amplifier stages provides 38-db overall gain, 45° K overall system input noise temperature, 60-Mc bandwidth, 0.1-db short-term gain stability, and 0.3-db long-term gain stability. A carefully designed cryogenic system maintains the amplifier refrigerated with only infrequent refilling of the dewar, i.e., once every 10 days.
Author

N64-12559 Radio Corp. of America, Camden, N.J. Defense Electronic Products

LASERS

H. R. Lewis et al [1963] 31 p refs

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2. RESEARCH ON LASER MATERIALS P. G. Herkart, M. Kestigian, and P. N. Yocom (RCA, Princeton) p 4-7 refs (See N64-12561 04-25)
3. DEVELOPMENT OF EFFECTIVE LASERS L. A. Murray, M. F. Lamorte, and F. L. Vogel (RCA, Somerville) p 8-11 (See N64-12562 04-25)
4. MODULATORS AND DEMODULATORS FOR LASER SYSTEMS D. J. Blattner and F. Sterzer (RCA, Princeton) p 12-15 refs (See N64-12563 04-25)
5. LASERS FOR RANGING APPLICATIONS E. Kornstein (RCA, Burlington) p 16-19 refs (See N64-12564 04-25)
6. LASER CHARACTERISTICS AND SOME POTENTIAL APPLICATIONS D. Karlsons and D. J. Parker (RCA, Camden) p 20-22 ref (See N64-12565 04-25)
7. MASERS IN SYSTEM APPLICATIONS L. C. Morris (RCA, Camden) p 23-26 refs (See N64-12566 04-25)
8. SUN-PUMPED CONTINUOUS LASER R. C. Duncan, Jr., Z. J. Kiss, and H. R. Lewis (RCA, Princeton) p 27 refs (See N64-12567 04-25)
9. WIDEBAND MICROWAVE PHOTOTUBES FOR LASER COMMUNICATION SYSTEMS D. J. Blattner, H. C. Johnson, F. Sterzer, and J. E. Reudy (RCA, Princeton) p 27-28 refs (See N64-12568 04-25)
10. A NEW GaAs LASER THAT CAN BE PUMPED ELECTRICALLY J. I. Pankove (RCA, Princeton) p 28 (See N64-12569 04-25)

N64-12560 Radio Corp. of America, Princeton, N.J.

THE LASER - AN INTRODUCTION

H. R. Lewis *In RCA, Camden, N.J. Lasers* [1963] p 2-3 refs (See N64-12559 04-25)

A brief insight into the novel properties of the laser is provided. The significance of the coherence of laser radiation is discussed, and the working principles of the laser are explained.
C. L. W.

N64-12561 Radio Corp. of America, Princeton, N.J.

RESEARCH ON LASER MATERIALS

P. G. Herkart, M. Kestigian, and P. N. Yocom *In RCA, Camden, N.J. Lasers* [1963] p 4-7 refs (See N64-12559 04-25) (Contract AF 33(616)8199)

The importance of the proper choice of materials for laser operation was emphasized because continuous operation, heat dissipation, and operating frequency are all functions of this parameter. Several criteria are given which laser materials must fulfill, and the steps involved in the preparation of laser materials are discussed. Some of the materials utilized in lasers are given, and other materials which have possible use are mentioned.
C. L. W.

N64-12562 Radio Corp. of America, Somerville, N.J.

DEVELOPMENT OF EFFECTIVE LASERS

L. A. Murray, M. F. Lamorte, and F. L. Vogel *In RCA, Camden, N.J. Lasers* [1963] p 8-11 (See N64-12559 04-25)

Effort has been devoted toward minimizing strain and impurities in grown laser crystals. Described are the effects on laser performance of the polish, parallelism, and reflecting surfaces of the prepared laser rod and the geometry of the pumping system, as well as the construction of absolute and relative threshold measurement apparatus.
Author

N64-12563 Radio Corp. of America, Princeton, N.J.

MODULATORS AND DEMODULATORS FOR LASER SYSTEMS

D. J. Blattner and F. Sterzer *In RCA, Camden, N.J. Lasers* [1963] p 12-15 refs (See N64-12559 04-25) (Contracts AF 33(616)-8199 and DA 36-039-SC-90846)

Wideband laser modulators that utilize crystals exhibiting linear electro-optic effects are under investigation, and work is being conducted on special microwave phototubes capable of demodulating light that has been modulated at gigacycle rates. Some of the techniques and some of the materials utilized in the systems are given.
C. L. W.

N64-12564 Radio Corp. of America, Burlington, Mass. Aerospace Communications and Controls Div.

LASERS FOR RANGING APPLICATIONS

E. Kornstein *In RCA, Camden, N.J. Lasers* [1963] p 16-19 refs (See N64-12559 04-25)

A prototype laser ranging system is discussed along with the basic considerations of laser ranging. The prototype unit, as packaged includes a sighting telescope, transmitter, and receiver optics. A review is given of early ranging systems, and the generation of single pulses is discussed. A technique for controlling laser output is also given, along with the range equation developed for laser ranging systems.
C. L. W.

N64-12565 Radio Corp. of America, Camden, N.J. Defense Electronic Products

LASER CHARACTERISTICS AND SOME POTENTIAL APPLICATIONS

Dainis Karlsons and Donald J. Parker *In its Lasers* [1963] p 20-22 ref (See N64-12559 04-25)

Favorable and unfavorable laser characteristics that affect applications, current trends and needs in laser equipment development, and potential laser applications are discussed. The ability to realize very small angular beamwidths in the optical region is the prime parameter of almost every application proposed for the laser, giving it the property of extremely efficient power transfer over long ranges. Small wavelengths associated with lasers mean that small oscillating structures

can serve as relatively high-gain antennas for radiating their energy. High noise temperatures, very difficult propagation characteristics for application through the earth's atmosphere, and rather poor efficiencies are all disadvantages of the laser. Some of the applications of the laser are as amplifiers; as a power generator capable of very-high-peak outputs; as well as average power levels; as detectors; in communication systems; and in radar systems. C.L.W.

N64-12566 Radio Corp. of America, Camden, N.J. Defense Electronic Products

MASERS IN SYSTEM APPLICATIONS

L. C. Morris *In its Lasers* [1963] p 23-26 refs (See N64-12559 04-25)

Attention was directed toward recent advances in maser development. This included the development of a traveling-wave maser; the construction of a small, compact maser utilizing rutile; the development of millimeter-wave masers; maser amplification at liquid-neon temperatures; and the application of masers in communications, such as in Telstar and Echo. The discussion also included maser noise temperature; antenna noise temperature; environmental noise sources; maser cooling systems; and future maser development. C.L.W.

N64-12567 Radio Corp. of America, Princeton, N.J.

SUN-PUMPED CONTINUOUS LASER

R. C. Duncan, Jr., Z. J. Kiss, and H. R. Lewis *In RCA, Camden, N.J. Lasers* [1963] p 27 refs (See N64-12559 04-25) (Contract AF 33(616)-8199)

Laser action has been achieved in a $\text{CaF}_2:\text{Dy}^{2+}$ system at liquid-neon temperature (27°K) using the sun as the pumping source. This laser action in the $\text{CaF}:\text{Dy}^{2+}$ system was reported at 2.36 microns. The low pulsed laser threshold, the long lifetime, and the convenient location of the broad pumping bands of this system make it especially suitable for sun-pumped operation. C.L.W.

N64-12568 Radio Corp. of America, Princeton, N.J.

WIDEBAND MICROWAVE PHOTOTUBES FOR LASER COMMUNICATIONS SYSTEMS

D. J. Blattner, H. C. Johnson, F. Sterzer, and J. E. Reudy *In RCA, Camden, N.J. Lasers* [1963] p 27-28 refs (See N64-12559 04-25) (Contract DA 36-039-SC-90846)

The RCA developmental A-1283 microwave phototube is schematically diagramed, and its operation is described. The light to be modulated passes through the optical window onto a transmission type photocathode. The photoelectrons emitted by the cathode are bunched at the modulation frequency of the light. As these electrons pass through a traveling-wave-tube type helix, they excite a traveling wave that is taken out at the output coupler. The tube with its focusing periodic permanent magnets is 18 inches long and weighs 5 pounds. C.L.W.

N64-12569 Radio Corp. of America, Princeton, N.J.

A NEW GaAs LASER THAT CAN BE PUMPED ELECTRICALLY
J. I. Pankove *In RCA, Camden, N.J. Lasers* [1963] p 28 (See N64-12559 04-25)

A very simple, electrically pumped, semiconductor laser was developed, that is comprised of a p-n junction diode in a wafer of gallium arsenide. The gallium arsenide was converted into a laser by altering its shape, by decreasing the contact resistance to reduce losses, and by increasing the current density through the junction. C.L.W.

N64-12587 General Electric, Co., Syracuse, N.Y.

SEMICONDUCTOR LASER AMPLIFIER TECHNIQUES (SEM-LAM)

Fred J. Demma Griffiss AFB, N.Y. Techniques Lab. Nov. 1963 24 p refs (Contract AF 30(602)-3111) (RADC-TDR-63-429; AD-425350)

This report describes the planning and use of the semiconductor laser diodes as light amplifier, and an oxygen gas laser as a source. Author

N64-12592 Cutler-Hammer, Inc., Deer Park, N.Y. Airborne Instruments Lab.

STUDY OF SOLID-STATE AND TRAVELING-WAVE MASER TECHNIQUES

J. A. De Gruyl, W. W. Heinz, S. Okwit, and J. G. Smith Griffiss AFB, N.Y. Tech. Lab. Nov. 1963 48 p refs (Contract AF 30(602)-2989) (RADC-TDR-63-461; AD-425402)

The purpose of this program is to develop improved maser techniques and apply them to an overall maser system. The specific areas of interest of this program are: (1) broad instantaneous maser bandwidth (500 Mc); (2) incorporation of solid-state power limiters to protect the maser from saturating; (3) use of superconducting solenoids to provide the magnetic field for the maser; and (4) investigation of the possibility of using the superconducting tunneling effect to provide the RF pump power to the maser. A theoretical analysis of the broad-band traveling-wave masers has been made, and several successful experiments have been performed. General expressions that show the important parameters affecting the broadbanding are given, and practical requirements for the structure and magnetic field are established. An analysis of the ferrite approach to the low-level limiter problem has been made. Author

N64-12870 American Optical Co., Southbridge, Mass. **EXPERIMENTAL VERIFICATION OF SUN-POWERED LASER TRANSMITTER [Final Report, Mar. 1962-May 1963]**

G. R. Simpson Wright-Patterson AFB, Ohio, AF Avionics Lab. Aug. 1963 119 p refs (Contract AF 33(657)-8619) (ASD-TDR-63-727; AD-420983)

This report details the effort expended on a program of design and experimentation leading to the delivery of an experimental model of a sun-powered laser transmitter. Analytical work is presented which resulted in the choice of Nd: CaWO_4 and Nd:glass as candidates for cw sun-powered operation. The design and fabrication of the transmitter mount, pump optics, and laser cavities is described. Cooling techniques developed (primarily oriented toward CaWO_4 although generally applicable to any solid laser material operating at room temperature) and the design of the cooling system are detailed. Experimental evaluation of a number of laser configurations of the materials discussed is presented. Evidence is given of quasi-continuous sun-powered operation of Nd:glass. Author

N64-12993 Hughes Research Labs., Malibu, Calif.

LASER DEVICES EXPLORATORY INVESTIGATION Interim Scientific Report No. 2, 1 Aug. 1963-31 Oct. 1963

H. V. Winston [1963] 55 p refs (Contract AF 33(657)-11650) (AD-423698)

Progress has been made in simplifying the theory of optical resonators so that cavities of any complexity, eventually including the pinhole mode selector, can be conveniently

analyzed. The simplified analysis also lends itself to optimization of resonator design. Chromium-doped synthetic spinel exhibits broad fluorescence line width, probably because of disorder in the structure, with chromium ions occupying neighboring sites in both tetrahedral and octahedral coordination. Other possible laser materials have been prepared and studied spectroscopically, including terbium-doped LaAlO_3 . A rotating mirror pulsed reflector laser has been built and its operating characteristics studied. The conditions for low beam divergence and high-power density at the focus have been established. Stimulated Raman scattering has been observed in a number of new liquids and in crystals of diamond, calcite, and sulfur, with the generation of a total of 36 new frequencies in the range from 6355 to 8980 Å. Author

N64-13238 Ohio State U. Research Foundation, Columbus Antenna Lab

TECHNICAL MEMORANDUM ON AN EXAMINATION OF THE ABSORPTION FLUORESCENCE, AND LASER RADIATION SPECTRA FOR SOME COMMERCIAL LASER CRYSTALS

John G. Meadors 30 Aug. 1963 31 p refs
(Contract AF 33(657)-10824)
(BPSN-3630-5237; AD-423567; Rept. 1579-1)

Three commercial laser crystals were studied and compared with published data on similar crystals. The absorption, fluorescence, and laser radiation spectra were examined for three rods in an attempt to shed some light on the tolerance of laser system design. C L W.

N64-13427 Technical Operations, Inc., Burlington, Mass
Thomas J. Skinner *In its* Invest of Coherent Optical Propagation Tech Doc Rept. Nov. 1963 p 1 70 refs (See N64-13426 05-01)

The need for a knowledge of the coherence of the emission of a laser in the design of a ground-to-satellite-to-ground optical communication system is described. In addition, methods, both theoretical and experimental, for measuring this coherence are presented. The signal and noise powers to be expected at various locations along the communications path are presented, but the effects of the atmosphere are ignored. A theoretical model of the propagation of light intensity and coherence in the atmosphere is developed. The results of this theoretical analysis along with some experimental data are used to repeat the previous power analysis, but the effects of the atmosphere are included. A general evaluation of the communications channel is given. Author

N64-13720 American Science and Engineering, Inc., Cambridge, Mass.

INVESTIGATION OF GROWTH OF OPTICAL CRYSTALS SUITABLE FOR LASER OPERATION Final Report [15 Jul.-30 Sep. 1963]

30 Oct 1963 21 p refs
(Contract AF 19(628)2470)
(ASE-466; AFCRL-63-518; AD-426488)

Among the tasks included in the investigation were: (1) the surveillance of optical crystals to determine those most suitable for laser operation; (2) the acquisition of background information necessary for the growth of selected crystals; and (3) the preparation of single crystals. Crystal-growth studies were confined to Verneuil furnace work, Czochralski furnace work, and growth from a flux. Results of studies on the growth of beryl and scapolite single crystals by flux crystallization are reported. R T K

N64-13744 Aerospace Corp., El Segundo, Calif
ELECTRONICS RESEARCH PROGRAM—OPTICAL MASER STUDIES Semiannual Technical Report [Final] 1 Jan.-30 Jun. 1963

M. Birnbaum and T. L. Stocker 25 Nov. 1963 32 p refs
(Contract AF 04(695)169)
(TDR-169(3250-22)TR-2; SSD-TDR-63-300; AD-426013)

CONTENTS:

1 EFFECT OF DIFFRACTION ON THE OUTPUT BEAM OF A RUBY LASER M. Birnbaum and T. L. Stocker p 1 11 refs (See N64-13755 05-25)

2 MULTIMODE OSCILLATION OF THE RUBY LASER NEAR THRESHOLD M. Birnbaum and T. L. Stocker p 12 22 refs (See N64-13756 05-25)

N64-13745 Aerospace Corp., El Segundo, Calif
EFFECT OF DIFFRACTION ON THE OUTPUT BEAM OF A RUBY LASER

M. Birnbaum and T. L. Stocker *In its* Electron Res. Program Opt. Maser Studies 25 Nov. 1963 p 1-11 refs Submitted for Publication (See N64-13744 05-25)

Observations were made of the near-field and far-field patterns of a ruby laser operated near threshold. In these observations, the beam diffraction effect predicted for diffraction by a small, elliptically shaped aperture was observed. This effect was a 90-degree rotation of the elliptical figure. The beam divergence was greater than that predicted using diffraction theory. R T K

N64-13746 Aerospace Corp., El Segundo, Calif
MULTIMODE OSCILLATION OF THE RUBY LASER NEAR THRESHOLD

M. Birnbaum and T. L. Stocker *In its* Electron Res. Program Opt. Maser Studies 25 Nov. 1963 p 12-22 refs Submitted for Publication (See N64-13744 05-25)

Experimental results were obtained demonstrating that many axial modes are present in the output of a ruby laser which is operated very close to threshold. Multimode operation was found to be the rule, even when the output of the laser appeared as a regularly spaced, exponentially damped series of spikes. Theoretical analysis of the laser oscillations indicates that the initial laser spike transient should damp out, leaving only the cw (continuous wave) oscillation of the laser. This effect was observed in a ruby laser operated close to threshold. In many cases, the initial train of laser pulses appeared to damp out and approach a cw level of oscillation. A cw beat frequency was often found to coincide with the cw light output. R T K

N64-13750 General Electric Co., Schenectady, N Y
SILICON CARBIDE DIODE "LASER"

R. N. Hall *In its* Semicond. Device Concepts 31 Oct 1963 p 47 58 refs (See N64-13747 05-25)

Luminescence from traveling solvent SiC diodes is discussed. It is concluded that the narrow emission line which has been reported is due to the spontaneous recombination of bound excitons and is unrelated to coherent light emission. Author

N64-13796 Cornell U., Ithaca, N Y
INVESTIGATION OF NEW CONCEPTS FOR MICROWAVE POWER GENERATION. LASER STUDIES Final Report

G. C. Dalman Griffiss AFB, N.Y., Rome Air Develop. Center, Dec. 1963 113 p refs
(Contract AF 30(602)-2833)
(RADC-TDR-63-465, Vol. 2; AD-427115)

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1. PRELIMINARY STUDIES OF ELECTRON EMISSION FROM TUNGSTEN INDIRECTLY HEATED BY A PULSED LASER G. C. Dalman 10 p refs (See N64-13797 05-25)
2. NOTE ON ELECTRON AND ION EMISSION FROM LASER-HEATED OXIDE CATHODES G. C. Dalman 7 p (See N64-13798 05-25)
3. DOUBLE-QUANTUM PHOTOELECTRIC EMISSION G. Wolga and H. Bowers 8 p refs (See N64-13799 05-25)
4. AN INVESTIGATION OF ELECTRON EMISSION FROM A TUNGSTEN SURFACE INDUCED BY A LASER BEAM L. A. Mac Kenzie 81 p refs (See N64-13800 05-25)

N64-13797 Cornell U., Ithaca, N. Y.

PRELIMINARY STUDIES OF ELECTRON EMISSION FROM TUNGSTEN INDIRECTLY HEATED BY A PULSED LASER
G. C. Dalman *In its Invest. of New Concepts for Microwave Power Generation. Laser Studies Dec. 1963* 10 p refs (See N64-13796 05-25)

An experimental and theoretical investigation of the emission of electrons, ions, and vertical particles from a tungsten cathode which is "surface-heated" by a laser beam is described. Principal emphasis is given the phenomenon of electron emission because of the interest in its application to the formation of a very dense electron beam. Two different experimental approaches are taken in obtaining electron emission. The first approach is to collect electrons which are "boiled off" the surface the laser beam strikes, whereas the second approach is to use a very thin tungsten ribbon to collect electrons from the surface opposite the one the laser beam strikes. Preliminary theoretical work describing these phenomena is discussed. Author

N64-13798 Cornell U., Ithaca, N. Y.

NOTE ON ELECTRON AND ION EMISSION FROM LASER-HEATED OXIDE CATHODES
G. C. Dalman *In its Invest. of New Concepts for Microwave Power Generation. Laser Studies Dec. 1963* 17 p (See N64-13796 05-25)

An exploratory study of the emission of electrons and ions from a cold barium oxide cathode surface was made to assess the usefulness of the conventional oxide cathode as a high-density current source. It is indicated that a laser-radiated oxide-coated cathode does not seem practical, since the coating readily breaks down. However, advantage may be taken of this effect to produce a pulsed source of high-density positive or negative ions. I. v. L.

N64-13799 Cornell U., Ithaca, N. Y.

DOUBLE-QUANTUM PHOTOELECTRIC EMISSION
G. Wolga and H. Bowers *In its Invest. of New Concepts for Microwave Power Generation Laser Studies Dec. 1963* 8 p refs (See N64-13796 05-25)

A theoretical study of double photon-induced photoelectric emission from single zinc crystals was made, and an experiment was designed to observe such emission. The double-photon absorption process leading to this photoelectric emission is a second-order process in the conventional perturbation treatment of the interaction of free, metallic electrons with

electromagnetic radiation; therefore, a ruby laser was used as a source of light in order to obtain the high fields necessary to produce this emission in measurable quantities. A detailed study of thermionic emission was made to distinguish the second-order photoelectric emission from simultaneously occurring thermionic emission. It was revealed that a high-frequency modulation of the laser light impinging on the crystal might well make the second-order effect observable. The quantum mechanical effects of this modulation on the second-order photoeffect were studied in detail along with the thermionic emission response to this modulation. The modulation is accomplished by means of the longitudinal Pockel's effect in KDP. I. v. L.

N64-13800 Cornell U., Ithaca, N. Y.

AN INVESTIGATION OF ELECTRON EMISSION FROM A TUNGSTEN SURFACE INDUCED BY A LASER BEAM
L. A. Mac Kenzie *In its Invest. of New Concepts for Microwave Power Generation. Laser Studies Dec. 1963* 81 p refs (See N64-13796 05-55)

The emission of electrons and ions from a metallic cathode when the surface is heated by a pulsed laser beam was investigated experimentally. The incident energy of the laser beam on the cathode ranged from 0.1 joules to 3 joules over a 300- μ sec pulse. A very large electron emission density was found under ordinary thermionic emission conditions. Also, a plasma discharge was obtained, which contained a large volumetric electron density. Some initial theoretical work is described as support for the experiments reported. Author

N64-13843 Aerospace Corp., El Segundo, Calif. Labs. Div.
ELECTRONICS RESEARCH PROGRAM. INFRARED AND ULTRAVIOLET DEVICE RESEARCH Semiannual Technical Note, 1 Jan.-30 Jun. 1963

J. Munushian 31 Oct 1963 39 p refs
(Contract AF 04(695)-169)
(TDR-169(3250-11)TN-2; SSD-TDR-63-299; AD-426153)

Coherent operation of a gallium arsenide injection laser has been achieved, and spectral characteristics, efficiency, and power capability have been studied in a large number of units. A phenomenological theory, based on a study of the spectral response of recombination radiation, has been developed which indicates that the radiation originates from a transition between the conduction band and a distinct zinc acceptor level. Various technological problems encountered in fabricating successful injection lasers have been explored in detail. The problem of zinc diffusion and uneven junctions has been alleviated by the use of a zinc-gallium diffusion source which permits good control over the zinc vapor pressure. Study of thermal decomposition of gallium arsenide, which can degrade the p-n junction in an injection laser, has resulted in a comprehensive picture of the nucleation and development of thermal decomposition in terms of the crystallographic parameters of the material. Author

N64-13844 General Electric Co., Syracuse, N. Y. Advanced Semiconductor Lab.

SEMICONDUCTOR DEVICE CONCEPTS Scientific Report No. 5B

N. Holonyak, Jr. et al 31 Oct. 1963 25 p refs
(Contract AF 19(628)-329)
(AFRL-63-552(B); AD-426254)

Halogen vapor transport synthesis of Ga(As_{1-x}P_x) and its preparation into laser junctions are described. Electrical and optical properties of Ga(As_{1-x}P_x) laser junctions are discussed.

The present limitations in these properties are related to material problems and the very early state of development of $\text{Ga}(\text{As}_{1-x}\text{P}_x)$, and are discussed in this context. Inhomogeneity problems, fluctuation of As:P ratio, and problems with deep-level contaminants are described and related to $\text{Ga}(\text{As}_{1-x}\text{P}_x)$ junction performance. Laser junctions are demonstrated which operate to wavelengths as short as 6470 Å (77° K). The prospect that $\text{Ga}(\text{As}_{1-x}\text{P}_x)$ will operate to wavelengths perhaps 100 Å shorter is mentioned. Author

N64-13912* Massachusetts Inst. of Tech., Cambridge
FREQUENCY STABILITY OF He-Ne Masers AND MEASUREMENTS OF LENGTH

T. S. Jaseja, A. Javan, and C. H. Townes Repr. from Phys. Rev. Ltr., v. 10, no 5, 1 Mar. 1963 p 165-167 refs (NASA Grant NsG-330)

Frequency stability of the oscillation of He-Ne masers at 1.153 was examined under controlled conditions. Frequency spread of the oscillation (stability over very short times) was reduced to about 20 cps, or about eight parts in 10^{14} ; frequency drifts as slow as a few tens of cycles per second were obtained; and the frequency resettability for a given maser over long periods of time was found to be somewhat less than 0.5 megacycle, or about one part in 10^9 . Short-term stability is within about one order of magnitude of the theoretical limit expected for these particular masers, and each of the results are measures of the masers' ability to determine lengths with great precision. R.T.K.

N64-13929* Massachusetts Inst. of Tech., Cambridge
GASEOUS OPTICAL MASERS AND THEIR APPLICATIONS
 A. Javan [1963] 35 p refs Presented at the Materials Sci. Colloq., Ithaca, N.Y., 5 Nov. 1963 Submitted for Publication (NASA Grant NsG-330)
 (NASA CR-55276) OTS: \$3.60ph, \$1.25 mf

A He-Ne system is described that is capable of producing oscillations at a large number of wavelengths. Its range covers a number of transitions in the red-yellow region of the spectrum as well as numerous transitions in the infrared region. The Ne atoms are responsible for the atomic transitions leading to maser oscillations. The He atoms provide a highly efficient source of excitation of the maser levels of Ne. Another gaseous discharge system is described in which dissociation of an oxygen molecule, O_2 , is used for the purpose of producing an oxygen atom in a given excited electronic state. An optical frequency oscillator is considered which consists of a gaseous discharge tube placed within an optical resonator. The resonator consists of two plane parallel (or two spherical) mirrors which are held rigidly by means of an external mechanical support. Such a configuration forms a Fabry-Perot interferometer. The following properties of optical masers are also discussed: the ability to detect small changes of length, frequency characteristics, frequency reproducibility, and length standard. R.T.K.

N64-13959 Technical Research Group, Inc., Melville, N.Y.
RESEARCH ON PROPERTIES OF LASER DEVICES Sixth Quarterly Technical Summary Report, 1 Sep.-30 Nov. 1963
 S. Rothberg and R. Kaplan, eds [1963] 63 p refs
 (Contract AF 49(638)-673; ARPA Order 256-62, Proj. Defender)
 (TRG-134-QTR-6, AD-427259)

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9. MODE SELECTOR EXPERIMENTS p 5-1 to 5-3
10. AMPLIFIER EXPERIMENT p 5-3 to 5-4
11. FLASH LAMP INVESTIGATION p 5-4 to 5-20 refs

APPENDIX

12. COHERENT DETECTION OF LIGHT SCATTERED FROM A DIFFUSELY REFLECTING SURFACE p A1 to A8 refs

N64-14116 Air Force Systems Command, Wright-Patterson AFB, Ohio AF Materials Lab.
THERMAL DIFFUSIVITY OF SOLIDS UTILIZING OPTICAL LASER ILLUMINATION Technical Documentary Report, Dec. 1 1962-Jul. 1, 1963

Gary L. Denman Oct. 1963 28 p refs
 (ASD-TDR-63-882, AD-425614)

The application of the flash technique for measurement of thermal diffusivity of solid materials at high temperatures is discussed. The use of the technique, its limitations, and particularly the analytical difficulties encountered in considering high-temperature radiation losses and specimen diathermancy are reviewed. The design of a high-temperature thermal diffusivity apparatus is outlined that uses a ruby laser pulse source, an indium-antimonide infrared detector system, and a high-temperature tantalum furnace. Author

N64-14149 Joint Publications Research Service, Washington, D.C.

PROSPECTS OF THE USE OF OPTICAL QUANTUM OSCILLATORS IN BIOLOGY AND MEDICINE

A. A. Vishnevskiy and S. N. Braynes 30 Jan. 1964 8 p Transl into ENGLISH of an article from Eksperim. Khirurg. i Anesteziol (Moscow), no 6, 1963 p 3-5
 (JPRS-22994, OTS-64-21438) OTS: \$0.50

The use of lasers in experimental biology is very promising. Since lasers are a source of high intensity radiation in a narrow spectral range, it is possible that they will prove to be an effective agent for delicate instrumentation in metabolic processes by the selective stimulation of molecules involved in these processes. Also, that laser radiation will display mutagenic properties is not out of the question. Mutations under such circumstances could be the result of the interaction of

infrared and visible radiation with molecular complexes, the carriers of heredity. Lasers have been successfully used in eye surgery. A beam was focused onto a small point on the retina, and detached parts of the retina were "welded" without damage to surrounding tissue. Malignant tumors have been cauterized with lasers. It is expected that lasers will play a large part in heart and nerve surgery and in the study of carcinomatous diseases. I.v.L.

N64-14316 Air Force Systems Command, Wright-Patterson AFB, Ohio

RING LASER TECHNIQUES FOR ANGULAR ROTATION SENSING

D. A. Guidice and W. L. Harmon Sep. 1963 43 p refs Presented at the ASD Sci. and Eng. Symp., Wright-Patterson AFB, Ohio, Sep. 18-19, 1963

(ASD-TDR-63-694; AD-425706)

The optical frequencies of the clockwise and the counter-clockwise beams traveling around the perimeter of the square "ring" depend on their respective optical path lengths which are equal in the absence of rotation. However, angular rotation alters the path lengths, resulting in different frequencies for the two traveling waves. The two waves are optically heterodyned in a photodetector, and the resultant beat frequency is directly proportional to the rotation rate of the "ring." An experiment verifying the existence of this phenomenon using a gas laser in the square "ring" configuration is given. The physics of mode pulling and various ways to minimize or bypass this problem are discussed in detail. Techniques for artificially separating the frequencies of the two waves by introduction of nonreciprocal elements into the optical path are described. Accuracy limitations caused by mechanical instabilities, excitation variations, and inherent stimulated emission line width are examined. Author

N64-14325 Army Signal Research and Development Lab., Fort Monmouth, N.J.

MAXIMUM GAIN FOR FORWARD AND BACKWARD WAVE OPTICAL MASER AMPLIFIERS

H. Jacobs, D. A. Holmes, L. Hatkin, and F. A. Brand Jul. 1963 30 p refs

(USAELRDL-TR-2375; AD-418338)

An analysis has been made of the mechanism of amplification in a device consisting of three media. The first medium is considered to be air, the second medium to be a crystal having a specific dielectric constant and distributed negative conductivity of constant value, and the third medium air. The equations for power gain in transmission and reflection are derived in a general manner. Following this, the condition on the length of the active region for maximum power gain in both forward and reflected modes of operation, as well as the magnitude of gain, is approximated. When the development is applied to the ruby optical maser, the length-producing maximum gain is found to be the same for both the reflection- and transmission-type amplifier. Furthermore, as the length of the crystal is increased, oscillations are predicted at a single optimum value of the product of the negative attenuation constant and length. Author

N64-14354 Michigan U., Ann Arbor Electron Physics Lab. **TRAVELING-WAVE MASER EXPERIMENTS USING RUBY AT X-BAND**

G. I. Haddad and D. H. Paxman Nov. 1963 34 p refs (Contract AF 33(657)-8050)

(Tech. Rept. 63: 05000-9-T; AD-425569) OTS: \$4 50

The characteristics of a traveling wave maser using ruby and a Karp-type slow-wave structure in the X-band frequency range are presented. Several possible operating points in ruby in this frequency range were examined, and the inversion ratio, paramagnetic absorption, and electronic gain at these points were measured. The experimental results are compared with the theoretical predictions. The problems involved in the design of the traveling-wave maser are discussed, and the performance that may be expected of a maser using good ruby crystals, a well-matched structure, and sufficient pump power is evaluated. Author

N64-14495 Philco Corp., Blue Bell, Pa. Sci. Lab.

COHERENT OPTICAL BEAM STEERING TECHNIQUES Final Report, 27 Dec. 1962-15 Sep. 1963

Leo W. Procopio, Frederic A. Jessen, Peter M. Nave, and Lewis J. Brown Griffiss AFB, N.Y., Tech. Branch, Jan. 1964 212 p refs

(Contract AF 30(602)-2901)

(RADC-TDR-63-450, Vol. 2; AD-428670)

The present state-of-the-art in coherent optical-signal generation is summarized. Generation, amplification, and modulation of coherent light is covered, along with optical-beam switching, power losses in optical components, propagation effects on coherent light, the far-field pattern of an array of lasers, laser-beam steering techniques, angular magnification techniques, and environmental sensitivity of optical components. C.L.W.

N64-14667 Radio Corp. of America, Camden, N.J.

DOPPLER OPTICAL NAVIGATOR Second Quarterly Progress Report, 6 Sep.-6 Dec. 1963

W. J. Hannan, L. J. Nicastro, G. Clubine, and T. E. Penn 19 Dec. 1963 92 p refs

(Contract AF 33(657)-11458)

(AD-426411)

The objective of this program is to determine the feasibility of novel laser techniques for Doppler optical navigation. The performance goal is the measurement of ground speed with 5 m/sec accuracy at a maximum altitude of 300 miles. Analysis and experimental results indicate that amplitude modulation can be used to improve the coherence of the return signal. At optical frequencies the ground is a diffuse reflector, whereas at a subcarrier frequency (or amplitude modulation frequency) it is not. As a result, a higher signal-to-noise ratio is realized with an amplitude-modulated wave, enabling velocity to be measured more accurately. An analysis of various filtering techniques showed that a subcarrier heterodyne receiver with a phase-locked oscillator filter will provide the best performance. Further, this analysis showed that optical heterodyne techniques will not improve the performance of the receiver. Author

N64-14684 Illinois U., Urbana Gaseous Electronics Lab. **SCATTERING OF RUBY LASER LIGHT BY GASES Scientific report No. 5 [Final]**

T. V. George and L. Goldstein Oct. 1963 102 p

(Contract AF 19(604)-7473)

(AFCRL-63-549; AD-427730)

In the present experiment, the angular distribution of the light scattered by gas molecules was measured from 45° to 135° from the direction of the incident beam in argon at 1 atm and xenon at 135 mm Hg of pressure. Experimental results show partial agreement with the Rayleigh theory. The lack of agreement is perhaps due to coherence effects. In argon, the scattered intensity shows a linear pressure dependence. No dependence of scattering cross section on the beam power level was

found in either monatomic or polyatomic gases. The differential scattering cross section at an angle of 60° with the beam was determined for various gases and compared with that calculated from known values of refractive indices. An empirical analysis of the discrepancy between the experimental observation and Rayleigh theory is also presented. Author

N64-14783 Corning Glass Works, N. Y.
GLASS LASER RESEARCH Annual Technical Report, May 1962-Jun. 1963

T. C. Mac Avoy, M. L. Charters, R. D. Maurer, W. H. Dumbaugh, and N. F. Borrelli 28 Jun. 1963 135 p refs
(Contract Nonr-3833(OO))
(LRC-63-991; AD-429010) OTS: \$10.50

A study of the spectral properties of neodymium-doped glasses has been undertaken with objects of (1) determining how the properties of glass influence the performance of a Nd-doped glass laser, and (2) developing the best possible glasses for high-power applications. The work consists of an extensive study of a wide variety of different glass compositions in parallel with a detailed study of the spectral properties of one glass. The main features of the influence of glass properties on spectral properties are now known. The silicates show the longest lifetimes and most intense fluorescence; the borates show the shortest lifetimes and weakest fluorescence. Since oscillator strengths are about equal for all glasses studied, the borates are apparently quenched. In addition to gross compositional effects, certain impurities, such as iron, copper, and nickel, quench the neodymium fluorescence. One of the more promising glasses has been prepared in the best optical quality available and is currently undergoing intensive study. Author

N64-14874 Grumman Aircraft Engineering Corp., Bethpage, N. Y. Research Dept.

THE ANALYSIS OF LASER OPERATION FROM A MICROWAVE CIRCUIT VIEW POINT

M. R. Wohlers Jul. 1963 15 p refs
(RN-163)

The linear microwave-circuit theory of lasers is developed by ascribing the microscopic parameters μ , and ϵ to lasing materials and then obtaining solutions to Maxwell's equations in the regions of interest. The approach is applied to a plane-wave Fabry-Perot interferometer filled with lasing material, and the threshold conditions for lasing or oscillation are determined. An example is presented which demonstrates the results as applied to a typical He-Ne laser. Author

N64-14895* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena

MASERS

W. H. Higa 26 Jul. 1962 21 p refs
(NASA Contract NAS7-100)

(NASA CR-53044, JPL-TM-33-95) OTS: \$2.60 ph. \$0.83 mf

The following discussion of masers is intended primarily for the electronics engineer interested in a quick introduction to the subject. After a concise review of the physics of induced radiative emission by atoms, a fairly complete discussion of use of atoms as circuit elements is given. The concluding sections describe the actual application of masers to sensitive receiving systems. Author

N64-15300* Massachusetts Inst. of Tech., Cambridge
MEDICAL PROGRESS. OPTICAL MASERS IN BIOLOGY AND MEDICINE

Ronald A. Malt, and Charles H. Townes Repr. from New Engl. J. Med., v. 269, 26 Dec. 1963 p 1417-1421 refs
(NASA Grant NsG-330)

The optical maser has broad applicability in biology and medicine because it makes available, for the first time, stable, highly directive, conveniently handled, coherent optical radiation of truly enormous intensity. As a consequence, light beams with equivalent temperatures of 10^{20} K are available in rays capable of being concentrated within a diameter of 1 micron, new electromagnetic effects of intense light become significant; signals may be sent long distances on modulated optical beams; and interference effects may be noted over path differences of thousands of kilometers rather than of a few meters. The uses of lasers and masers as a heating source, in spectroscopy and photography, and in long-range monitoring are discussed. R.T.K.

N64-15365 Ohio State U. Research Foundation, Columbus Antenna Lab.

SOME EXPERIMENTAL MEASUREMENTS OF THE CHARACTERISTICS OF Q-SWITCHED LASERS

Raymond E. Whitacre 15 Nov. 1963 52 p refs
(Contract AF 33(657)-10824)

(BPSN-3630-5237; Rept. 1579-5; AD-429006)

Measurements of the variation in peak power output from a Kerr cell, Q-switched ruby laser and a rotating-roof prism, Q-switched ruby laser as a function of the parameters of the laser systems are reported. Emphasis is placed on optimizing the power output from the Kerr cell system by considering the effects of variations in pumping energy, output end reflectivity, delay time between flashlamp firing and Q-switching, reflector alignment, and cavity length. A detailed description of the physical arrangement and the operation of the two systems is presented. Author

N64-15371 Ohio State U. Research Foundation, Columbus, Antenna Lab.

MICROWAVE THEORY AND THE BREAKDOWN OF GASES BY RUBY LASER RADIATION

Richard G. Tomlinson 31 Dec. 1963 24 p refs
(Contract AF 33(657)-10824)

(Rept. 1579-7; AD-428865)

Microwave breakdown theory is extrapolated to the 6943 A. ruby laser wavelength. The need for a breakdown criterion other than that for the critical plasma frequency, sometimes used in microwave breakdown, is shown. A suitable criterion is developed from the solution of the electron-density continuity equation, including recombination loss. A solution for the breakdown electric field strength, or power density, for the pulse ruby laser in air as a function of pressure is obtained. The effect of varying pulse duration, initial electron density, and characteristic diffusion length is shown. A minimum power density of 10^{12} w/cm² is predicted for the breakdown of air by ruby laser radiation. Author

N64-15465 Centre National d'Etudes des Telecommunications (France)

LASERS AND SEMICONDUCTORS [LASERS ET SEMICONDUCTEURS]

M. G. A. Bernard and G. Duraffourg In AGARD, Paris Light and Heat Sensing 1963 p 185-191 refs In FRENCH (See N64-15452 07-23)

The possibility of obtaining, in semiconductors, the emissions stimulated by the transitions between the conduction bands and the valence bands, between one of these bands and an impurity level of the interdictive band, or by annihilation

excitation is discussed. If the state of occupation of these bands and the levels are characterized by the pseudolevels of Fermi, the condition necessary for a stimulated emission is $\Delta F > h\nu$, where ΔF is the difference between the pseudolevels of Fermi of the initial state and the final state of the transition, and $h\nu$ is the energy of the induced photon. The direct transitions from band to band in InAs and InSb and the transitions between the bands of conduction and the acceptor levels of Zn and In, respectively, in Ge and Si are presented. An analysis is made of the various causes of loss, and the particular cases in which conditions for obtaining the laser effect can be realized are discussed. Transl. by I.v.L.

N64-15466 Massachusetts Inst. of Tech., Cambridge
CHARACTERISTICS OF A GASEOUS OPTICAL MASER
 A. Javan *In* AGARD, Paris Light and Heat Sensing 1963 p 193-197 refs (See N64-15452 07-23)

This report is concerned with the basic operation and frequency characteristics of gaseous optical masers; the presently operating He-Ne maser is particularly emphasized. The use of this device as a standard of length and some of its spectroscopic applications are discussed. Author

N64-15467 Bell Telephone Labs., Inc., Murray Hill, N.J.
CONTINUOUSLY PUMPED SOLID STATE OPTICAL MASERS
 W. S. Boyle and D. F. Nelson *In* AGARD, Paris Light and Heat Sensing 1963 p 199-206 refs (See N64-15452 07-23)

In this paper two specific devices, the chromium-doped aluminum oxide (ruby) and neodymium-doped calcium tungstate solid-state masers, are examined. A comparison is made between two different pumping geometries; the importance of the spectroscopic properties of maser crystals in determining the pumping requirements is illustrated. Author

N64-15469 Hughes Research Labs., Malibu, Calif.
LASERS FOR COMMUNICATIONS AND OPTICAL RANGING
 George F. Smith *In* AGARD, Paris Light and Heat Sensing 1963 p 221-234 refs (See N64-15452 07-23)
 (Contract AF 33(616)-8233)

The three key properties of the laser light source—brightness, focusability, and monochromaticity—enable it to transmit information efficiently to a distant point even in the presence of other undesired radiation "noise," because that noise can be rejected by a filter. In a one-way communications link with constant-aperture diffraction-limited antennas, the fraction of transmitted power that is received is proportional to the square of the frequency. Signal fluctuation noise, however, increases linearly with frequency, so the S/N ratio improves only linearly with frequency. At optical frequencies, aiming problems are likely to limit the useful degree of beam collimation; thus, on the basis of bandwidth per transmitted watt, a laser space-communications link will be competitive with, but not drastically superior to, a futuristic microwave space link. The high-power pulse performance of ruby lasers is promising for optical ranging. Although rudimentary ranging systems have operated only at several kilometers, it now appears feasible to range off the moon. Author

N64-15614 Army Signal Research and Development Lab., Fort Monmouth, N.J.
ON THE FEASIBILITY OF AN ETTINGSHAUSEN SEMICONDUCTOR LASER

H. Mette, E. Schiel, and C. Loscoe Jun. 1963 14 p refs (USAELRDL-TR-2374; AD-413364)

This report theoretically investigates the possibility of achieving stimulated recombination radiation in a semiconductor by an alternate method to the injection diode. The results show that an excess concentration of recombination carriers sufficient to initiate laser action may be obtained in semiconductors by drift and deflection in a magnetic field (Ettingshausen effect). However, further data are required to calculate the exact size of the threshold value. Although the current densities required for operating the device appear of an order similar to those required for injection diodes, the pumping method is based entirely on bulk effects. Therefore, the device offers a number of practical advantages over junction devices, such as a larger emitting area and fast response time. The design of a possible Ettingshausen laser is discussed in detail, and problem areas for future work are listed. Author

N64-15686 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

AN ASTRO-SHIP CALLS THE EARTH; SUPER LONG-DISTANCE COMMUNICATIONS WITH A SPACE SHIP

V. A. Sokolov and Yu. F. Ivanov 27 Aug. 1962 17 p Transl. into ENGLISH from Nauka i Zhizn (Moscow), no. 2. 1962 p 13-19 (FTD-TT-62-721/1+2; AD 286611)

The necessary creation of new radio engineering and communications for use in interplanetary space is considered. For this purpose, testing of visible-color, infrared, and ultraviolet waves (the use of the "optical window" of the atmosphere) is indicated. Many projects using light in this manner are in progress, including the use of solar beams, and artificial light sources, such as the plasma cloud and lasers. R.L.K.

N64-15708 Army Signal Research and Development Lab., Fort Monmouth, N.J.

ZEEMAN EFFECT IN GAS DISCHARGE LASERS

Rudolf G. Buser, Johann J. Kainz, and John J. Sullivan Jun. 1963 15 p refs (USAELRDL-TR-2322A; AD-412799)

Recent measurements of the intensity of the emission of a gas discharge laser are discussed in terms of Zeeman effect. By application of magnetic fields, it seems possible to induce mode switching. Author

N64-15757 Syracuse U., N.Y.

SUBMILLIMETER MASER INVESTIGATIONS WITH RUBY
 Technical Report, 1 Jun. 1962-31 Dec. 1963

J. Hermance and G. Wessel [Dec. 1963] 44 p refs (Contract Nonr-669(18)) (AD-429381)

A theoretical study backed by a number of experiments has been carried out to investigate the feasibility of generating submillimeter radiation in ruby at 0.035-cm wavelength (870 kmc) between the 2E levels. To achieve this generation, two different methods have been explored and are briefly described. In the first method both 2E levels of ruby are populated by providing pumping action between the 4F and the 4A_2 states that require green pumping light of about 5,600 Å. In the second method two ruby crystals are employed, the first one to generate the R_2 line, which is used to pump the second ruby. C.L.W.

N64-15978 Lockheed Missiles and Space Co., Sunnyvale, Calif.

LASER TECHNOLOGY: AN ANNOTATED BIBLIOGRAPHY [JAN. 1962-FEB. 1963]

Helen B. McCormick, comp. Feb. 1963 98 p refs (SB-63-23; Rept 5-73-63-6)

Advances in laser technology are reported against the background of comprehensive treatment of laser characteristics and action; new materials evidencing laser action; laser applications and problems, and the continuing research that is making such applications more practicable. Subject coverage is selective and representative rather than complete. The inclusion of recent bibliographies and evaluations (Section I: Bibliographies, and Section II: Laser Action and Applications) provides the reader the opportunity for more detailed background and perspective. Author

N64-16086 Aerospace Corp., El Segundo, Calif. Electronics Research Lab

ELECTRONICS RESEARCH PROGRAM: INVESTIGATION OF GAS LASERS AND NONLINEAR OPTICAL EFFECTS Semiannual Technical Note, 1 Jan.-30 Jun. 1963

T. S. Hartwick, E. R. Peressini, R. C. Ward, and C. J. Buczek 21 Dec. 1963 39 p refs (Contract AF 04(695)-169)

(SSD-TDR-63-351; TDR-169(3250-21)TN-2; AD-430129)

An analysis is given of frequency modulation of a gas laser by a time-varying axial magnetic field. Preliminary experimental results are reported. A helium-neon laser employing a d.c.-excited discharge between close-spaced parallel electrodes has yielded laser action at a wavelength of 1.15μ . Analysis and experimental results show that the "gain-switching" technique will be very useful for the repeated, reliable production of short, high-power laser pulses needed in the study of nonlinear optical effects and in optical radar. Author

N64-16441 Hughes Research Labs., Malibu, Calif. Quantum Physics Dept.

LASER DEVICES EXPLORATORY INVESTIGATION Interim Scientific Report No. 3, 1 Nov. 1963-31 Jan. 1964

H. V. Winston [1964] 77 p refs (Contract AF 33(657)-11650)

(AD-429856)

CONTENTS

1. SINGLE MODE AND CW INVESTIGATION p 3-23 refs
2. MATERIALS GROWTH AND SPECTROSCOPY p 25-32 refs
3. NONLINEAR OPTICAL EFFECTS p 33-47 refs
4. STIMULATED RAMAN SCATTERING AND RELATED PARAMETRIC EFFECTS. APPENDIX Robert W. Hellwarth p A-1 to A-27 refs (See N64-16442 08-23)

N64-16442 Hughes Research Labs., Malibu, Calif. Quantum Physics Dept.

STIMULATED RAMAN SCATTERING AND RELATED PARAMETRIC EFFECTS. APPENDIX

Robert W. Hellwarth *In its* Laser Devices Exploratory Invest. [1964] p A-1 to A-27 refs (See N64-16441 08-25)

Stimulated Raman scattering (SRS) of light from frequency ω_p to the Stokes shifted frequency $\omega_p - \omega$ has been extensively studied. Under certain experimental conditions this SRS is accompanied by weaker emission at frequencies $\omega_p + n\omega$ where n may take on many positive integral values.

It is the purpose of this paper to make a first step toward a fundamental understanding of this multiplet of lines (which is called an "SRS ladder") by calculating a somewhat unrealistic model problem, where the Raman active material is enclosed in a perfectly conducting cavity and illuminated by an absolutely monochromatic source. The power in the SRS ladder lines is estimated by assuming that the output originates from amplified quantum noise, and powers are found that are not unlike those from experiments. Ways to extend the model and to improve the approximations are discussed. Author

N64-16644 General Electric Co., Syracuse, N.Y. SEMICONDUCTOR LASER AMPLIFIER TECHNIQUES (SEMLAM)

Griffiss AFB, N.Y. RADC, Jan. 1964 26 p (Contract AF 30(602)-3111) (RADC-TDR 63-553; AD-430340)

The construction of a cryogenic dewar was accomplished, including the design of the jig to hold diodes, special pulse circuits to provide proper current pulse to the diode, the construction of an oxygen gas laser, and measurement data on tungsten package GaAs CW diodes. Author

N64-16665 Princeton U., N.J. Plasma Physics Lab ON THE PRODUCTION OF AN ENERGETIC PLASMA BY MEANS OF HIGH ENERGY, SHORT DURATION LASER PULSES

John M. Dawson 18 Sep. 1963 24 p refs (Contract AT(30-1)-1238)

(MATT-222)

Calculations are presented that show that a laser pulse delivering powers of the order of 10^{10} watts to a liquid or solid particle with dimensions of the order of 10^{-2} cm will produce a hot plasma with temperatures in the range of several hundreds of eV. To a large extent, the plasma temperature is held down by its rapid expansion and cooling. This converts much of the energy supplied into ordered energy of expansion. This ordered expansion energy can amount to several Kev per ion. If the expanding plasma can be caught in a magnetic field and its ordered motion can be converted to random motion, this might be utilized as a means for filling controlled thermonuclear fusion devices with hot plasma. Author

N64-16711* Hughes Aircraft Co., Culver City, Calif. STUDY ON OPTICAL COMMUNICATIONS FROM DEEP SPACE Interim Progress Report, 7 Jan.-1 Feb. 1963

Kenneth L. Brinkman 1963 50 p refs

(NASA Contract NAS9-879)

(NASA CR-55814, SSD-3101S) OTS, \$460ph, \$170mf

A preliminary survey of operating lasers and their characteristics is presented. Particular emphasis is placed upon CW operating lasers (solid state and gas), the properties of the gallium arsenide lasers, and solar pumped lasers. The characteristics of operating lasers that are relevant to their use as optical communications systems components is also discussed. Bibliographies on the following subjects are presented: laser materials and devices, modes and optical properties of laser emission, modulation, mixing, detection, etc., and theory, pumping, and miscellaneous considerations. P V E

N64-16744* Massachusetts Inst. of Tech., Cambridge RAMAN AND PHONON MASERS

R. Y. Chiao, E. Garmire, and C. H. Townes [1963] 29 p refs
Lecture presented at Summer School Session of the Intern.
School of Phys. "Enrico Fermi", Verenna, Italy, Aug. 1963
(NASA Grant Nsg-330)
(NASA CR-53103) OTS: \$2.60 ph, \$1.07 mf

When the very intense beams of light generated by optical masers interact with matter, they tend to excite various degrees of freedom of both the matter and the radiation field, and sometimes such excitations are quite large. At certain threshold intensities, instabilities set in that transfer energy very rapidly from the beam to other electromagnetic or mechanical modes of the system. Some of these processes are discussed. The generation of coherent molecular oscillations or phonons by interaction between intense maser beams and matter is discussed in detail. The instabilities produce the observed intense Raman radiation, along with coherent molecular vibrations. The possibility that they also lead to generation of intense high-frequency sound waves and infrared radiation was also investigated. R.T.K.

N64-16774 Lincoln Lab., Mass. Inst. of Tech., Lexington
SOLID STATE QUARTERLY PROGRESS REPORT, DIVISION 8 [1 Oct.-31 Dec. 1963]

Benjamin Lax et al 6 Feb. 1964 17 p refs Prepared for Electron. Systems Div.
(Contract AF 19(628)-500)
(ESD-TDR-64-15; AD-429866)

Activities are reported in the following areas: (1) solid-state device research; (2) laser research; (3) materials research; (4) band structure and spectroscopy of solids; and (5) magnetism and resonance. R.T.K.

N64-16834 Columbia Radiation Lab., New York, N.Y.
THE OPTICAL MASER APPLIED TO BRILLOUIN SCATTERING SPECTROSCOPY Progress Report No. 2, 1 Apr. 1963-30 Sep. 1963

H. Cummins N. Knable, Y. Yeh, L. Gampel, and J. Barrett Sep. 1963 3 p refs
(Grant DA-ARO(D)-31-124-G380. NSF Grant GP-438)
(AD-432142)

Progress is reported as follows: The apparatus was considerably refined, and heterodyning efficiencies approaching the theoretical maximum were obtained. The ultrasonic tank employed in measuring Bragg-scattering frequency shifts was permanently incorporated into the apparatus as a means of displacing the frequency of the optical local oscillator beam, thereby permitting single-sideband detection at a convenient frequency. Additional improvements of the radiofrequency detection circuitry were executed, which now permit spectral scans with continuously variable resolution between 6 and 6,000 cps. J.E.T.

N64-16868 Lincoln Lab., Mass. Inst. of Tech., Lexington, Mass.

SOLID STATE RESEARCH, 1963

R. J. Arnott et al 26 Dec. 1963 73 p refs
(Contract AF 9(628)-500)
(ESD-TDR-63-584; AD-427340)

Among the achievements summarized are: (1) InSb diode lasers, which emit coherent radiation at 5.2μ , have been fabricated. (2) A relatively large ($\sim 1 \times 1/2 \times 1/4$ in.) completely single crystal of n-type ($\text{In}_0.8\text{Ga}_{0.2}$) has been grown from the vapor phase. Injection lasers have been fabricated from this crystal. (3) A GaAs infrared radar has been operated. (4) The problem of coherent Stokes and anti-Stokes radiation, associated

with stimulated Raman emission from nitrobenzene, has been analyzed. (5) Measurements of the Seebeck coefficient (α) and resistivity (ρ) have been made as a function of temperature on doped single crystals of SnO_2 . (6) The structure of the high-pressure phase of SnTe has been determined by X-ray diffraction measurements made at pressures above the transformation pressure of 18 kbar. (7) A new method for deriving a reduced Liouville equation for a subsystem from the Liouville equation of the total system has been obtained. (8) Very satisfactory agreement between theory (theory of complex spin configurations found in cubic spinels possessing relatively strong B-B interactions) and experiment have been obtained in the case of several Cr spinels. I.v.L.

N64-16962 Johns Hopkins U., Silver Spring, Md. Applied Physics Lab.

AN ANNOTATED BIBLIOGRAPHY OF SOVIET LITERATURE ON MASERS AND LASERS

E. J. Blau 15 Sep. 1963 69 p 231 refs
(Contract N0w-62-0604-c)
(TG 230-B1; AD-421701)

The purpose of this annotated bibliography is to list and abstract all of the Soviet literature, published before 1963, that deals directly with masers and lasers. Articles that serve as partial foundation and general background to the subject have been omitted. The earliest reference is the doctoral dissertation by V. Z. Fabrikant, dated 1939. R.T.K.

N64-17343 Joint Publications Research Service, Washington, D.C.

EXCITING A LIGHT SOURCE WITH A COMMON AXIS PULSE LASER

Hsu Chi-jen, Chang Tsun-k'uei et al *In its* Transl. on Communist China's Sci. and Technol. No. 75 19 Mar. 1964 p 29 40 refs Transl. into ENGLISH from K'o Hsueh T'ung Pao (Peking), no. 11, 1963 p 39-41 (See N64-17342 09-01) OTS: \$2.25

A new, common-axis, cylindrical, xenon flash lamp for exciting a light source for a ruby light, quantum oscillator is described. The lamp is designed to match a 4-cm-long and 0.5-cm-diameter ruby rod. The lamp tube is made of "Pali-k'o-ssu" glass or crystal material. The input energy of the glass lamp is up to 800 Joules, whereas that of the crystal lamp can be raised to more than 3,000 Joules. Pure nickel is used as the electrodes. The lamp was observed to have the following advantages: (1) It provided high flash power and high efficiency without an axial magnetic field. (2) The energy was higher than that of a linear tube lamp with the same electrode interval. (3) The structure was tight. (4) It is an ideal tool for theoretical study. I.v.L.

N64-17870 International Business Machines Corp., Yorktown Heights, N.Y. Thomas J. Watson Research Center
INJECTION LASER STUDY Second Quarterly Progress Report, 1 Sep.-30 Nov. 1963

G. J. Lasher, F. Stern, and K. Weiser [1963] 54 p refs
(Contract DA-36-039-AMC-02349(E))
(AD-430696)

CONTENTS:

1. PROPOSED BISTABLE INJECTION LASER p 6 28 refs (See N64-17871 10-25)
2. FAR-FIELD RADIATION PATTERN p 29 32 refs (See N64-17872 10-23)
3. ELECTRICALLY BISTABLE Mn- AND Zn-DIFFUSED GaAs INJECTION LASER p 33 41 refs (See N64-17873 10-25)

4 ELECTROLUMINESCENCE OF Mn DIFFUSED P-N JUNCTIONS p 42 47 refs (See N64-17874 10 25)

5 ATTEMPTS TO DETECT FLUORESCENCE FROM RARE EARTH DOPE GaAs AND InP p 48 (See N64-17875 10 25)

N64-17871 International Business Machines Corp., Yorktown Heights, N.Y. Thomas J. Watson Research Center

PROPOSED BISTABLE INJECTION LASER

G. J. Lasher, F. Stern, and K. Weiser *In its Injection Laser Study* 1963, p 6 28 refs (See N64-17870 10 25)

The possibility of constructing a bistable injection laser from a single, semiconducting crystal diode is analyzed. A GaAs diode that emits recombination radiation from electrons injected into an active layer on the p side of the junction is considered. The bistability depends upon nonlinear absorption of light by a portion of the p side of the junction. Its operation is somewhat analogous to a bistable microwave maser recently constructed by Gerritsen. The analysis is made for the liquid helium temperatures, assuming the recombining electrons are in the exponential tail of the conduction band. Bistability is predicted, assuming either a constant or a square-root dependence of the density of states in the valence band on energy. For liquid nitrogen temperature, the numerical results of Lasher and Stern, which refer to parabolic conduction and valence bands, are used. R I K

N64-17873 International Business Machines Corp., Yorktown Heights, N.Y. Thomas J. Watson Research Center

ELECTRICALLY BISTABLE Mn- AND Zn- Diffused GaAs INJECTION LASER

G. J. Lasher, F. Stern, and K. Weiser *In its Injection Laser* 1963, p 33 41 refs (See N64-17870 10 25)

The electrical and optical properties of GaAs diodes prepared by subsequent diffusions of Mn and Zn into n-type GaAs are discussed. Such diodes exhibit a negative resistance over part of their I-V characteristics, and have interesting electroluminescent properties. Laser action was obtained in these structures. The achievement of lasing action is believed to be the result of improved diffusion techniques, which result in very straight diffusion fronts. Lasing thresholds, mode structures, directionality, and near field patterns of a number of these diodes were examined. At 77°K, the most striking difference between these and ordinary lasing diodes is the fact that lasing action was found to occur some 10 microns away from the p-n junction. There are also indications of a different temperature dependence of the threshold current from that found for ordinary lasers; however, the experiments underlying the observation are preliminary. R I K

N64-17961 Wheeler Labs., Inc., Great Neck, N.Y. **STUDY OF LASER OUTPUT PARAMETERS AND MEASUREMENT TECHNIQUES** Final Report, 20 May-20 Nov. 1963

E. R. Schriener, H. M. Heinemann, H. W. Redlien, and R. A. Kaplan. Griffiss AFB, N.Y., RADC, Feb. 1964, 163 p refs

(Contract AF 30(602) 3132)

(Rept 1182, RADC TDR 63 564 AD 433174)

A detailed study has been made of the laser parameters associated with system applications involving both energy and information transfer. The approach to the study has included a discussion of the fundamental properties of

EM radiation, independent of specific laser types, the determination of system parameters, and their relation to these fundamental properties. The specific output parameters of the solid state, gaseous, and diode lasers were computed theoretically, and measurement principles were reviewed. The study has resulted in definitions of a wide variety of parameters needed to describe the many different properties of laser radiation in space and time. The results are presented in a set of tables of indicated system parameters, system relations, and the applicable laser parameters. Theoretical considerations based on the concept of the laser as a multimode oscillator have led to the adoption of conceptual models for each of the three laser types. Author

N64-18023 Raytheon Co., Waltham, Mass. Research Div. **MULTIMODE OSCILLATIONS IN SOLID STATE MASERS** Interim Scientific Report

H. Stutz and C. Tang, Oct. 1963, 29 p refs

(Contract AF 19(628) 3226)

(AFCL 63 917 AD 43282)

Previous work on the effects of slow spatial cross relaxation is extended. Off-axis modes are included in the calculations, and thus it becomes possible to calculate the number of oscillating off-axis modes as a function of the various laser parameters. In this way the expected beam angle of a laser can be predicted. A more detailed analysis of the spiking behavior is given. It is shown that both regular and irregular spiking trains may be obtained depending upon the laser parameters and the pump power. Author

N64-18132* General Electric Co., Philadelphia, Pa. Valley Forge Space Technology Center

OPTICAL SPACE COMMUNICATIONS SYSTEM STUDY, VOLUME II: SYSTEM TOPICS - PART ONE Final Report

7 Feb. 1964, 97 p refs

(NASA Contract NASw-540)

(NASA CR 53467) OTS \$8 60 ph

Results are presented of tests on star observations, on photomultiplier performance, and on the effects of the atmosphere on laser propagation. The study supported the belief that optical communication has the potential to replace radio and to perform unique functions in many space situations. Certain methods are proposed to overcome the restriction of receivers to small area collecting optics in the atmosphere and to high quality optics in any case. C L W

N64-18133* General Electric Co., Philadelphia, Pa. Valley Forge Space Technology Center

OPTICAL SPACE COMMUNICATIONS SYSTEM STUDY, VOLUME III: SYSTEM TOPICS - PART TWO Final Report

7 Feb. 1964, 123 p refs

(NASA Contract NASw-540)

(NASA CR 53466) OTS \$10 10 ph

The following are discussed with respect to optical space-communications systems: (1) photomultiplier detectors, performance of photomultiplier detectors on signals that are close to the noise level of the detector; (2) effect of atmospheric turbulence on laser propagation, absorptive attenuation, scattering (nonabsorptive attenuation), seeing effects caused by random fluctuation in the index of refraction of the air, and potential high energy effects; and (3) laser optics, transmitting optics, receiving optics, filtering, and detection of faint sources. P V E

N64-18566 Air Force Systems Command, Griffiss AFB, N. Y. Rome Air Development Center

PLASMA DIAGNOSTICS USING THE RAMAN EFFECT
Raymond P. Urtz, Jr. Mar. 1964 84 p refs Theoretical Portion of Work Performed by Republic Aviation Corp
(Contract AF 30(602)-3071)
(RADC-TDR 64-5: AD-434761)

A novel plasma diagnostic technique is presented that utilizes the Raman scattering of a laser beam from a plasma. Detection of the Raman scattering will provide qualitative information on the molecular and ionic species present in a plasma. By measuring the relative intensities of the Stokes and anti-Stokes Raman lines, determination can be made of the density and temperature of the individual species present in a plasma. The theory correlating the Raman intensity with the species density and temperature is presented along with preliminary experimental results. The applicability of this technique in connection with various types of plasmas is shown.
Author

N64-18579 Corning Glass Works, N. Y.
GLASS LASER RESEARCH Semiannual Technical Report, Jul.-Dec. 1963

T. C. Mac Avoy, M. L. Charters, N. F. Borrelli, M. E. Vance D. Weinberg et al 30 Jan. 1964 29 p refs
(Contract Nonr-3833(00), Proj. Defender)
(AD-431753)

The properties of a soda-lime-silicate laser glass, known as Code 0580 glass, are reported; they include spectral properties, glass properties, composition, laser threshold, and impurity analysis. The variation of the optical path through a laser rod during flash illumination has been observed. Factors important in understanding this effect are discussed, and experimental measurements of them are described. Laser damage experiments on 17 different kinds of glass, selected for their unique properties, have been analyzed. Four possible mechanisms have been advanced. An analysis has shown that long lifetimes and high neodymium concentrations are the most important parameters for high-energy storage. A new technique has been developed to measure thresholds using constant spectral and temporal pump light.
Author

N64-18771 New Mexico U., Albuquerque Engineering Experiment Station

REFLECTION AND REFRACTION IN A NON-TURBULENT ATMOSPHERE WITH MOVING INTERFACES

Donald C. Thorn and James E. Leeman Jan. 1964 16 p ref
(Contract AF 29(600)-3445)
(EE-101, AD-435985)

The purpose of this report is to supply a basis for engineering design in high-precision laser radar systems. It is demonstrated that, for a moving interface, the angle of reflection is not equal to the angle of incidence, and that Snell's Law does not apply (in its usual form) to the angle of transmission. In addition, relations are developed that appear to be useful and convenient for a practical calculation of the appropriate angle. Also, it is demonstrated that the usual Doppler-shift expression must be modified to account for the angular deviation. Because of the angular and frequency modifications, it appears that a corner reflector will not produce precisely the same results as a properly orientated flat reflector. However, this difference in results is not computed.
I v. L.

N64-18904 General Electric Co., Schenectady, N. Y. Research Lab.

SEMICONDUCTOR DEVICE CONCEPTS Scientific Report No. 6

31 Jan. 1964 55 p refs
(Contract AF 19(628)-329)
(AFCL-64-135; AD-433975)

Halogen transport synthesis of $\text{GaAs}_x\text{P}_{1-x}$ has been studied further, using a rotating tube vertical furnace. Laser quality material has been produced using Te and Si as the donor impurities, and the homogeneity has been improved. Measurements of composition, carrier concentration, and optical transparency are reported. A "red-black" effect has been discovered that has been found to be helpful in selecting laser quality regions from $\text{GaAs}_{1-x}\text{P}_x$ ingots having compositions near the direct-indirect limit. The possibility of achieving coherent light emission from junctions in wide band gap II to VI compounds has been examined. A preliminary evaluation of a heterojunction laser structure is described. A systematic study of the introduction and behavior of acceptor impurities in CdS has been started.
Author

N64-19066 General Electric Co., Syracuse, N. Y. Radio Guidance Operation

FEASIBILITY DEMONSTRATION OF A NEW PLASMA DIAGNOSTIC PROBE Final Report [1 Dec. 1962-30 Dec. 1963]

D. Kingsland 27 Mar. 1964 58 p refs
(Contract AF 19(628)-2378; ARPA Order 363)
(AFCL-64-254; Rept. 64A025; AD-435677)

The purpose of this contract was to demonstrate the feasibility of utilizing the Thomson-scattered radiation of a ruby laser to determine electron temperature and density in a helium plasma. A thyratron tube was modified to create the plasma, and a spectrometer was used to observe the Doppler profile of the Thomson-scattered radiation. Langmuir-type probes built into the modified thyratron were used as an independent check on electron density and temperature. There was little correlation between the laser scattering and the check provided by the Langmuir probes. A precise determination of electron temperature was not realized using the laser scattering data. An electron density of approximately $10^{15}/\text{cc}$ was, however, deduced from the magnitude of the scattered energy. Opposed to this was a value, approximately $6 \times 10^{12}/\text{cc}$, derived from the Langmuir probe data. Theoretical effort supports the laser scattering data and negates the validity of the Langmuir probe data.
Author

N64-19490* Rochester U., N. Y. Inst. of Optics

THE USE OF A SINGLE PLANE PARALLEL PLATE AS A LATERAL SHEARING INTERFEROMETER WITH A VISIBLE GAS LASER SOURCE

M. V. R. K. Murty Repr. from Appl. Opt., v. 3, no. 4, Apr. 1964 p 531-534 refs
(NASA Contract NASr-14)

A high-intensity interference pattern can be obtained in a shearing interferometer with the use of a visible gas laser and a simple construction. The high intensity of the laser per unit of solid angle gives an interference pattern that is visible in room light. The narrow spectral width of the source allows a simple plane parallel plate to be used to obtain the desired shear.
Author

N64-19665 Technical Operations Research, Burlington, Mass.
LOSS FACTORS AFFECTING RUBY LASER SYSTEMS Final Report

J. Masters, J. Ward, and E. M. E. Murray 31 Jan. 1964 75 p refs
(Contract AF 19(628)-405)
(AFCL-64-151; TO-B-64-5, AD-437608)

Efficient high-power output performance of ruby lasers depends on reducing the effect of storage losses, or losses of atoms from the excited state that occur during the pumping phase, and internal propagation loss suffered by stimulated emission. Both types are strongly dependent on geometric parameters. Internal propagation losses were significant in ruby ($\sim 35\%$ per transit in a typical 2-in. ruby rod). Storage loss due to nonlinear de-excitation during pumping is important under atypical conditions. Preliminary measurements of the nonlinear de-excitation due to spontaneous-emission amplification were performed under nonstandard operating conditions and showed $\sim 50\%$ inversion loss for a large, cooled ruby sample. The limitations of simple physical models of ruby laser systems are discussed in detail. Important influences of mode coupling and mode selection on the threshold condition for oscillation in ruby lasers are reported. Author

N64-19674 Cutler-Hammer, Inc., Deer Park, N.Y.
STUDY OF SOLID-STATE AND TRAVELING-WAVE MASER TECHNIQUES

J. A. De Gruyl, W. W. Heinz, S. Okwit, and J. G. Smith Griffiss AFB, N.Y., RADC, Mar. 1964 42 p refs (Contract AF 30(602)-2989) (RADC-TDR-64-115, AD-437906)

The major effort has been confined to broadbanding the maser and investigating the limiters. A comb-type slow-wave-structure test section, 3.3-in. long, has been designed and fabricated. This structure has an exceptionally large slowing-bandwidth product and relatively low loss. The structure bandwidth was greater than 500 mc with an average slowing factor of about 70 and an insertion loss of less than 3 db. Ferrite isolator disks, integrated in the structure, provided isolation approaching 20 db. Two novel approaches to the limiter were analyzed and measured: a thin film superconducting limiter and a bulk semiconductor limiter. Both approaches appear to be capable of yielding the desired protective characteristics. Author

N64-19788* Cornell Aeronautical Lab., Inc., Buffalo, N.Y.
ON THE POSSIBILITY OF SIMULATING METEOROID IMPACT BY THE USE OF LASERS Topical Report

William J. Rae and A. Hertzberg, Apr. 1964 44 p refs (NASA Contract NAS3-2536) (NASA CR-54029, CAL AI-1821-A-1) OTS \$4 60 ph

This report discusses the possibility of studying the problem of meteoroid damage by using a laser to simulate the conditions of high-speed impact. The characteristics of the light output from a laser allow a strongly focused pulse of energy to impinge on the target surface. The principal content of the report is a critical examination of the extent to which such irradiation simulates the conditions of impact by a solid projectile. The present state of knowledge concerning meteoroid impact damage is briefly reviewed, and the capabilities of a laser are examined. Author

N64-19974 Radio Corp. of America, Moorestown, N.J. Missile and Surface Radar Div.
ELECTRO-OPTICAL ATTITUDE MEASURING SYSTEM - A DESIGN STUDY

Bedford, Mass., Electron Systems Div., Oct. 1963 191 p refs (Contract AF 19(628)-2900) (ESD-TDR 63-624, AD-428002)

A design study is documented to investigate a method of electro-optically determining the attitude of a missile from lift-off to 50,000 ft. The attitude in terms of pitch, yaw, and

roll is obtained from a single station by lasers illuminating two missile-borne retroreflector packages. Each retroreflector package has as one of its components a Savart plate. The reflected radiation is returned to the receivers where the beams are separated and analyzed by a polarization sensitive system to determine polarization states induced at the Savart plates as the missile's attitude changes. Author

N64-20308 Office of Naval Research, London (Gt. Brit.)
SOME ELECTRONICS RESEARCH AT THE ROYAL RADAR ESTABLISHMENT, MALVERN

Glenn H. Keitel, 14 Feb. 1964 17 p refs (ONRL-9-64, AD-438830)

The present status of research in the following areas is summarized: (1) semiconductor physics; (2) infrared and basic material work, particularly, attention, to the construction of a tube for the generation of mm-wavelength radiation; (3) cryogenics; (4) theoretical physics and mathematics; (5) electronic circuits; (6) quantum electronics; (7) high-power modulators; (8) applied physics and technical services; (9) radio astronomy; and (10) radio meteorology. I v L

N64-20398 Naval Ordnance Test Station, China Lake, Calif. Aviation Ordnance Dept.
A MEANS OF AIMING A LASER BEAM

L. W. Nichols, Jan. 1964 5 p (NAVWEPS-8491, NOTS-TP-3446, AD-429341)

The retrodirective reflecting properties of a corner reflector can be used to aim a laser beam. When portions of a corner reflector are placed in front of a laser and its aiming telescope, then an image of the laser beam is superimposed on the telescope image to show the exact target area being illuminated by the beam. Author

N64-20399 Stanford U., Calif. Microwave Lab.
MICROWAVE RESEARCH Quarterly Status Report No. 19, 1 Aug.-31 Oct. 1963

C. F. Quate et al., Dec. 1963 29 p refs (Contract Nonr-225(48)) (ML-1122, AD-428767)

Activities are reported in the following areas: (1) acoustic-wave amplification studies; (2) optical masers; (3) ferrited nonlinear propagation; and (4) transverse-field interactions of a beam and plasma. R T K

N64-20658 Joint Publications Research Service, Washington, D.C.

ACTIVE MATERIALS WHICH CAN PRODUCE OPTICAL MASER ACTION

Sung-hao Liu. In its Transl. on Communist China's Sci. and Technol., no. 82, 12 May 1964 p 23-56 refs. Transl. into ENGLISH from K'o-hsueh T'ung-pao (Peiping), no. 2, 17 Feb. 1964 p 127-139 (See N64-20657 13-01) OTS \$2 25

A detailed discussion is presented on impurities-excited fluorescent crystals and semiconductors. The discussion is divided as follows: (1) gas special features of gas active materials, the structure that produces optical maser action in gas active materials, He-Ne gaseous optical maser; (2) impurity-excited fluorescent crystals over-compensated metal ions excited fluorescent crystals, rare earth ions excited fluorescent crystals, actinide series ions excited fluorescent crystals; (3) impurities-excited fluorescent glass; (4) organic fluorescent materials organic compounds of the aromatic family, rare earth chelated compounds, light sensitive organic compounds, organic materials that produce Raman coherent emission; (5)

semiconductor active materials—special features of semiconductor active materials, some possible different plans to accomplish stimulated emission by using semiconductors, GaAs p-n junction; and (6) the development trend of active materials.
P.V.E.

N64-20718 Aerospace Corp., El Segundo, Calif. Materials Sciences Lab.

FLAWS IN RUBY LASER CRYSTALS; GENERAL RESEARCH

K. Janowski and H. Conrad 21 Feb. 1964 8 p ref (ATN-64(9236)-10)

A description is presented of the microscopic flaws, barely visible to the unaided eye, that were found in some ruby laser crystals. These flaws have the appearance of streaks or filaments. Upon examination of the ruby crystal with an optical microscope, it was found that the streaks or filaments were not continuous but consisted of a large number of closely spaced spheroids (voids or precipitate particles), approximately 2μ in diameter. These spheroids lay along a chord of the original disk boule. Similar streaks or filaments were observed in a 90° ruby rod that was deformed in compression at 1,900° C. These filaments had the same appearance and character as those observed on the as-grown boule and were inclined to the basal plane at about the same angle. Upon etching the deformed sample in fused potassium bisulfate, it was found that many of the filaments terminated at subgrain boundaries. Furthermore, X-ray back reflection studies indicated that the filaments lay along the $\{10\bar{1}1\}$ rhombohedral planes.
R.T.K.

N64-20740* Little (Arthur D.) Inc., Cambridge, Mass.
DESIGN AND CONSTRUCTION OF 4.2° K MASER REFRIGERATOR SYSTEM Final Report

William E. Gifford et al 1 Dec. 1962 44 p refs (NASA Contract NAS7-100; JPL-950076) (NASA CR-56168; C-63774) OTS: \$4.60 ph

The refrigeration system was designed to cool and maintain a small electronic device at 4.2 K, and is capable of continuous operation under a wide range of ambient conditions (0° to +160 F). The system reduces approximately 750 mw of useful refrigeration at 4.2 K with corresponding smaller amounts of refrigeration at those lower temperatures that are within the capability of the compressor unit. The refrigerator unit consists of a refrigerator circuit, a mechanical drive unit, a Joule-Thompson expansion circuit, a radiation shield, and a vacuum insulation jacket with associated vacuum pumps. The compressor unit consists mainly of a modified commercially available, hermetic compressor and a helium purification system.
P.V.E.

N64-20847 Naval Research Lab., Washington, D.C. Optics Div.

TRANSMISSION OF RUBY LASER LIGHT THROUGH WATER

J. A. Curcio and G. L. Knestrick Oct. 1963 12 p refs (NRL-5941; AD-412313)

The attenuation coefficients of filtered Potomac River water were measured at the ruby laser wavelength, 6.943A, and at 3 wavelengths in the green region of the spectrum where the attenuation is near the minimum. The path of the light beam, which was at a depth of 2.2 m, was varied from 6 to 36 m in the laser light observations and from 15 to 73 m for the green light observations. Narrow-band filters were used to restrict the passband of the system, and the field of view of the receiver was limited to 12°. The attenuation coefficient obtained at 6.943A was $5.45 \times 10^{-3} \text{ cm}^{-1}$, and the value obtained at 4.900A was $8.6 \times 10^{-4} \text{ cm}^{-1}$. Evidence was

found for some small particle scattering. As an underwater light source, the ruby laser is severely handicapped by the fact that its emission occurs at a wavelength that is highly attenuated by water.
Author

N64-20848 Army Signal Research and Development Agency and Lab., Fort Monmouth, N.J.

CORRELATION OF LASER THRESHOLD WITH THE OPTICAL QUALITY OF RUBY

C. M. Kellington, M. Katzman, and S. K. Poultney Dec. 1963 10 p refs (USAE/RDL-TR-2408; AD-431243)

A program is discussed that was instituted to: (1) correlate optical parameters with crystal growth conditions; (2) correlate optical parameters with laser characteristics; and (3) relate the laser characteristics to the crystal growth conditions. The object of the program is to control the Verneuil method of growing ruby so that it yields optimum laser crystals. The threshold for laser action was measured for each crystal by noting the time delay between the flash-lamp pulse and the onset of laser emission for fixed-pump geometry and energy. A table is presented that lists the optical properties for crystals with high- and low-threshold regions for a given density. It is noted that, in general, the high-threshold crystals have more small-angle scatter, fewer parallel faces, less optical parallelism, larger linewidth, and a more uneven optical thickness than the low-threshold crystals. Large-angle scatter did not appear to be correlated to threshold.
P.V.E.

N64-20850 Library of Congress, Washington, D.C. Aerospace Information Div.

SOVIET ADVANCED LASER PROPOSALS Surveys of Soviet-Bloc Scientific and Technical Literature [1956-1964]

13 May 1964 33 p refs (AID-P-64-35; AD-600291)

This review article covers the following areas: (1) controllable lasers based on the Zeeman effect, (2) gamma lasers, (3) fiber-optics lasers, (4) Raman scattering lasers, (5) plasma lasers, (6) chemical lasers, and (7) lasers based on organic materials.
R.T.K.

N64-20905 Hughes Research Labs., Malibu, Calif.
LASER DEVICES EXPLORATORY INVESTIGATION Interim Engineering Report No. 4, 3 Feb.-30 Apr. 1964

H. V. Winston [1964] 22 p refs (Contract AF 33(657)-11650) (AD-600267)

The fabrication and testing of sapphire quarter-wave plates for use with ruby in a novel longitudinal mode selector were completed. Testing of the elliptical pumping cavity for cw operation was started. A new setup made possible the growth of doped lanthanum trifluoride crystals of relatively high quality. Flame fusion techniques were used to make single crystal Gd_2O_3 . The optical spectra of the newly grown $\text{LaF}_3:\text{Pr}^{3+}$ and Gd_2O_3 were obtained. Microwave spectra of chromium-doped LaF_3 were observed, and the identification of the resonances observed in terbium-doped LaF_3 was continued. Anomalies in the emission angles of anti-Stokes cones from various stimulated Raman scattering (SRS) materials were measured, and possible explanations examined experimentally. The most recent measurements show that both Stokes and anti-Stokes cones in typical SRS materials have angle spreads greater than 1° and wavelength spreads of the order of 20 A.
Author

N64-20992 General Dynamics/Electronics, Rochester, N.Y. Quantum Physics Lab.

RELIABILITY OF GASEOUS OPTICAL LASERS USING NOBLE GAS ACTIVE MEDIA

Jack E. Taylor *In* RADC Phys of Failure in Electron., vol 2 [1963] p 436-449 refs (See N64-20967 14-09)

Whether this model can be extended to times of importance to reliability of long-lived gas lasers without considerable change in formulation is not known at present. Several simplifying assumptions about the sorption of oxygen in the presence of active rare gases were made. Considerable additional data must be obtained on the rate of electrical cleanup of oxygen in all glass laser systems before the analysis can be applied to operating systems. One area that has been neglected here, but which will be of importance, is concerned with how oxygen or other contaminants prevent or extract energy from the energy cycle used in the laser. A combination of optical- and mass-spectrometry will be required to provide detailed model parameters. In summary, this paper has pointed out some of the problems associated with the interaction of the rare-gas laser medium with discharge tube materials and contaminants. It is expected that a continuing study of the physical system interactions will lead to sufficient understanding of the various failure mechanisms of gas lasers that their reliability can be specified with relatively few simple measurements. Author

N64-21012 California U., Livermore Lawrence Radiation Lab

FEASIBILITY CONSIDERATIONS IN THE APPLICATION OF LASER DIAGNOSTICS TO PLASMAS OF DENSITY $\sim 10^{13}$ cm^{-3}

Robert E. Ellis and Frederick R. Kovar 16 Mar. 1964 28 p refs

(Contract W-7405-ENG-48)
(UCRL-7712) OTS: \$0.75

The feasibility of the use of a pulsed ruby laser system for the purpose of determining plasma electron temperature and density is examined, assuming an electron density of $\sim 10^{13}$ cm^{-3} and an electron temperature of ~ 100 eV. The signal, to be obtained by detecting a portion of the Doppler-broadened spectral distribution of laser radiation scattered at 90° to the incident beam, is calculated. Effects of plasma bremsstrahlung, stray light from the primary laser beam, and light from excited, partially ionized atoms are estimated. It is pointed out that, in principle, the unpolarized light from the plasma may be discriminated against by splitting the light entering the viewing system into two mutually perpendicular, polarized components, which are then to be detected separately and nulled out in a differential amplifier. A brief consideration of the use of laser interferometry for the determination of plasma electron density is included. Author

N64-21020 Dayton U., Ohio Research Inst

COHERENT OPTICAL RADAR PARAMETERS AND TARGET REFLECTIONS Technical Documentary Report, 1 Jul. 1962-30 Jun. 1963

Werner R. Rambauske Wright-Patterson AFB, Ohio, Res and Tech Div, Apr 1964 127 p refs

(Contract AF 33(657) 9014)
(RTD-TDR-63-4148, AD-600272)

The problem of the reflection of ruby laser pulses from artificial targets is investigated. The parameters of intensity

distribution over the cross section of a laser beam (in the 0.5 - to 3 -joule energy range), and the time history of this intensity within one pulse (in the $1/2$ - to 1 -ms duration range) were measured and evaluated in different distances for the ruby rod up to 75 m. Reflection characteristics for different standard geometrical bodies and different standard surface materials were derived experimentally and theoretically for incoherent white illumination and were compared with laser illumination. The change of time history of a single pulse after reflection from the target, due to the target's shape, was studied. This change when compared with the undistorted pulse from the rear of the ruby permits conclusions about the shape of the target. Author

N64-21051 Massachusetts Inst of Tech., Cambridge Lab. for Insulation Research

[OPTICAL MASER AND LIGHT MODULATION] Final Report, Feb. 1962-Jun. 1963

S. J. Allen, K. Linden, B. Di Bartolo, M. Mack, R. Peccei et al [1963] 8 p refs

(Grant AF AFOSR-62-317)
(AD-428961)

Research activities have been conducted as follows: (1) Studies of coherent emission from ions in glass hosts showed that: (a) fluorescence lifetimes of such ions (rare earth) in glasses are determined by spontaneous emission rather than by radiationless processes; and (b) fluorescent line widths are broadened by variations in ionic environment to the order of 100 cm^{-1} to 200 cm^{-1} . (2) Optical harmonic generation in ammonium dihydrogen phosphate resulted in generation of coherent light in the green spectral region ($5,300$ Å). (3) A rate equation analysis was made of optical maser emission. (4) An investigation of excited state spectroscopy and secondary absorption in optical masers is discussed. (5) Investigation of the extension of maser techniques to submillimeter wavelengths and of the problems of generation, detection, and modulation in this range were made. (6) An investigation of radiationless and phonon-assisted decay of excited ions in solids is discussed. PVE

N64-21185 Radio Corp. of America, Camden, N.J. Defense Electronic Products

DOPPLER OPTICAL NAVIGATOR Third Quarterly Progress Report, 6 Dec. 1963-6 Mar. 1964

W. J. Hannan, L. J. Nicastro, T. E. Penn, and J. Vollmer 20 Mar. 1964 59 p refs

(Contract AF 33(657)-11458)
(AD-434227)

The objective of this program is to determine the feasibility of novel laser techniques for Doppler optical navigation. The performance goal is the measurement of ground speed of a satellite, traveling at a velocity of $10,000$ m/sec at an altitude of 300 miles, with an accuracy of 5 m/sec. For the velocities involved, the optical Doppler shift can be as high as 20 Gc, which is beyond the state-of-the-art of tracking receivers. For this reason subcarrier modulation techniques were investigated. Analysis of the subcarrier case, which takes into account atmospheric attenuation, solar background radiation, coherence of the subcarrier return, and practical system constants, indicates that required transmitter power is more than an order of magnitude beyond the present state-of-the-art of laser transmitters. Assuming that the power required becomes available, it is important to note that the subcarrier approach is feasible for high altitudes. Investigation of the

subcarrier approach to low-altitude aircraft reveals that it offers little, if any, improvement over conventional microwave systems. However, a CW system employing an optical heterodyne receiver does offer potential advantages. Operation of a thermoelectrically cooled gallium-arsenide laser transmitter was demonstrated. This refrigeration technique makes injection lasers practical. Author

N64-21375 Westinghouse Electric Corp., Baltimore, Md. Aerospace Div
DEVELOPMENT OF MILLIMETER AND SUBMILLIMETER MASER DEVICES Interim Technical Report No. 3, 1 Oct. 1963-31 Jan. 1964

W. E. Hughes [1964] 30 p refs
(Contract AF 33(657)-10472)
(AD-432597)

The third reporting period was devoted to the study of iron-doped zinc tungstate as a possible new quantum amplifier material. The solutions to the spin Hamiltonian were obtained so that identification of energy levels is possible, and a computer program for the solution of radiation-induced transition probabilities was established. Since the dielectric constant of the zinc tungstate is considerably lower than that of the materials used previously, it was necessary to make several changes in the experimental apparatus. Several pumping techniques, including the five-level technique, will be investigated in zinc tungstate. During this period, operating points were chosen from the computer solutions of the Hamiltonian. Author

N64-21669 Air Force Cambridge Research Labs., Bedford, Mass. Terrestrial Sciences Lab.
FEASIBILITY OF A LUNAR OPTICAL RANGING EXPERIMENT Research Report

Robert L. Iliff and Michael S. Tavenner Dec. 1963 24 p refs
(AFCL-63-908; AD-434586)

A lunar ranging experiment using a high-energy pulsed laser is discussed giving special attention to the required minimum return signal, interfering radiation, detector devices, and pulse length. Author

N64-21682 United Aircraft Corp., East Hartford, Conn. Research Labs.
CONTROL OF LASER PERFORMANCE Quarterly Status Report No. 3, Dec. 26, 1963-Mar. 25, 1964

G. E. Danielson, Jr. and A. J. De Maria 31 Mar. 1964 17 p refs
(Contract DA-19-020-AMC-0170(A))
(C-920083-9; AD-434166)

Studies of the effect on laser output control of varying the refractive index of a medium in a laser cavity are being carried out with ultrasonic, electric, or magnetic means. Initial tests of the glass prism light shutter were conducted with a visible He-Ne laser beam mechanically chopped at approximately 83 cps to facilitate modulation percentage measurements. Experimental results showed that approximately 80% modulation was obtained. Gating of a 3 X 1/4 in. diam. Nd³⁺ doped glass laser rod with 1-mc transducers bonded to the ends produced an increase in peak and total output power. An improved ultrasonic standing wave can be obtained with the use of one complete cylindrical transducer instead of two 180° focusing sections. Author

N64-21709 Williamson Development Co., Inc., West Concord, Mass.

STUDIES AND INSTRUMENTATION FOR ACCELERATING PARTICLES IN A PLASMA Final Report

Joseph G. Kelley, Allen G. Rubin, and Ivan A. Nichols Bedford, Mass., AFCRL, 29 May 1964 29 p
(Contract AF 19(628)-309)
(AFCL-64-412; AD-600761)

The plasma Betatron was designed, built, and operated as proposed. Suggestions are made for future modifications. Also discussed are transient optical measurements. An image converter camera was incorporated into the existing experiments. Infrared devices, particularly a laser interferometer, were designed. The 6-in. arc driven shock-tube facility is described. Significant modifications to the vacuum system and the high voltage system were completed. Various instrumentation problems are discussed. Presented are theoretical details for two experiments—the infrared interferometer and the plasma-conductivity measurement. Author

N64-21784 Martin Co., Orlando, Fla.

LASERS AND THEIR EFFECTS Annual Progress Report, 1 Jul. 1963-1 Mar. 1964

James H. Burkhalter 1 Apr. 1964 49 p
(Contract DA-49-193-MD-2456)
(OR-3885; AD-433218)

A description is given of the work performed for the Biological Effects of Lasers Program of the Office of the Surgeon General. This includes the design and construction of a research laser and associated instrumentation for the attack on problems of interest to the biological researchers of the program. A discussion is presented of the more important problems to date of the various biological researchers, together with the approaches used. Author

N64-21982 Air Force Systems Command, Wright-Patterson AFB, Ohio Research and Technology Div.

ANALYSIS OF GENERALIZED OPTICAL ARRAYS

Edwin B. Champagne Dec. 1963 30 p refs
(RTD-TDR-63-4138; AD-431567)

The extension of the present array theory to arrays of optical sources is beset with difficulties, and some of these difficulties are studied. Statistical theory is applied to a generalized array in an attempt to predict what degradation of array factors may be anticipated for such factors as amplitude deviations, various polarizations, frequency bandwidths, phase deviations, and mechanical alignment errors. Author

N64-22052 Harvard U., Cambridge, Mass. Cruft Lab.

STATISTICAL FLUCTUATION IN NONLINEAR OPTICAL PROCESSES

J. Ducuing and N. Bloembergen 18 Nov. 1963 44 p refs
(Contract Nonr-1866(16))
(TR-430; AD-434890)

Second-harmonic generation is considered, and it is shown that the presence of several incoherent modes in the laser beam leads to a discrepancy between the real and the measured nonlinear constant, and introduces a certain amount of randomness in the ratio between the square of the fundamental intensity and the second-harmonic intensity. Experimental results with a single-pulse ruby laser are described that

demonstrate the part played by the spatial modes in the mechanism of fluctuations of the second-harmonic production. The theory of fluctuations in higher order nonlinear processes is briefly discussed. Conversion and related experiments are presented considering the case of microwave generation. It is shown that a reduction factor for the generation of beats in a photocathode should be taken into account in this experiment. N.E.A.

N64-22222 Lincoln Lab., Mass. Inst. of Tech., Lexington
SOLID STATE RESEARCH, 1963
 9 Mar. 1964 82 p refs
 (Contract AF 19(628)-500)
 (ESD-TDR-64-16; AD-435023)

This report on solid-state research includes the following: solid-state devices, lasers, solid-state materials, band structure and spectroscopy of solids, and magnetism and resonance. J.R.C.

N64-22237 ITT Communication Systems, Inc., Paramus, N. J.

APPLICABILITY OF LASER TECHNIQUES Status Report
 W. S. Litchman 13 Mar. 1964 80 p refs
 (Contract AF 19(628)-3358)
 (ICS-64-TR-379; ESD-TDR-64-249; AD-434378)

This report presents laser communication techniques that can be integrated into the AIRCOM System to satisfy current and estimated future Air Force requirements. Described, in detail, are the characteristics of the laser and problems related to light generation, modulation, and detection. These characteristics will aid in visualizing a number of possible applications in which a laser communication link can be advantageously employed in the AIRCOM system. Some of the possible applications are described. N.E.A.

N64-22454* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena

NOISE PERFORMANCE OF TRAVELING-WAVE MASERS
 W. H. Higa Repr. from IEEE Trans. on Microwave Theory and Tech., v. MTT-12, no. 1, Jan. 1964 2 p ref
 (Contract NAS7-100)
 (NASA-CR-56283; JPL-TR-32-506)

A review of the noise performance of traveling-wave masers (TWM) is given. It is shown that when the gain per unit length of structure is low, the equivalent noise temperature of the TWM can become appreciable. The discussion indicates the need for careful design of a TWM when operating at elevated temperatures (4.2° K or higher), which the present state-of-the-art of closed-cycle refrigerators requires. R.T.K.

N64-22547 Dayton U. Ohio Research Inst
THEORETICAL AND EXPERIMENTAL REFLECTION FROM DIFFERENT REFLECTING BODIES IN THE FAR FIELD AND LASER BEAM MEASUREMENTS WITH RESPECT TO INTENSITY AND TIME Interim Report
 Werner Rambaucke, Ronald R. Gruenzel, and Michael K. Barnoski Jun 1963 91 p
 (Contract AF 33(657) 9014)
 (AD 423641)

This paper reports how classical laws of Lambertian reflection were applied to the reflection problem of the standard geometrical bodies, and how equations were derived that are valid for the far field (indefinite distance). Numerical solutions of these equations are plotted and shown in a set of curves.

Likewise, a far-field situation was simulated in a photometric cavity, and the series was repeated under great care and accuracy. The received curves were strikingly similar to the theoretical ones, indicating that both theoretical and experimental solutions are correct. N.E.A.

N64-23926 Naval Ordnance Test Station, White Oak, Md.
HAIR-TRIGGER OPERATION OF A NEODYMIUM LASER
 David L. Caskey May 1964 82 p refs Based on M.S. Thesis—MIT
 (NOLTR-64-32; AD-436893)

A laser system has been devised that provides a preselected number of laser bursts at controlled intervals by shaping the output of the optical pump light in a suitable manner. Two techniques were used. A system was constructed to demonstrate the principle. The working model provides up to three 15 μ sec laser bursts per firing, while the time between bursts is controlled by preselected delays of from 50 μ sec to 500 μ sec. The peak power output is several kilowatts. Although the model employs a 2-in. X 1/4-in. Neodymium-doped glass laser, the method is applicable to a wide variety of laser materials and sizes. Author

N64-23959 Air Force Systems Command, Griffiss AFB, N.Y. Rome Air Development Center
IN-CAVITY LASER MODULATION STUDY
 Anthony D. Rugari May 1964 25 p refs
 (RADC-TDR-64-129; AD-601660)

A theoretical and experimental study was performed to investigate a laser modulation technique capable of providing a flat frequency response over the range of 30 cps to 30 mc/s with a modulation index of 0.5 or greater. The technique involved the introduction of controllable losses to the laser cavity by alternate alignment and misalignment of the cavity reflectors. This was to be accomplished by insertion of an electro-optic prism in the cavity and varying the angle of deviation of the exit beam from the prism by electrically controlling the magnitude of the index of refraction of the prism. The transmission losses associated with the electro-optic prism were experimentally found to be greater than the gain of the laser cavity. Thus, oscillations could not be maintained with the electro-optic prism in the cavity. The major factors contributing to the transmission losses were found to be reflection losses and an inherent birefringence of the crystalline materials. Pertinent theoretical discussions and experimental results are included in the report. Author

N64-23975 Ohio State U. Research Foundation, Columbus Antenna Lab.

FOCUSING OPTICS FOR INTENSE LASER SOURCES
 Edward K. Damon 15 Dec. 1963 40 p refs
 (Contract AF 33(657)-10824)
 (Rept. 1579-6; AD-441643)

Problems associated with the focusing and control of extremely intense laser beams are examined. It is shown that an optical system resembling a classical Galilean telescope is suitable, in principle, for such a task; the design procedure for such a system is demonstrated for typical examples. It is possible to correct the aberrations of such a system to give excellent performance, and the correction is essential in order to hold spherical aberration to a tolerance level. The use of spheric surfaces or zonal correction plates can further improve the performance of such a system if the original laser beam is highly collimated. J.L.D.

N64-24067 Sperry Gyroscope Co., Great Neck, N.Y. Radiation Div.

DESIGN CRITERIA STUDY FOR HIGH POWER VOLTAGE RESEARCH FACILITY Second Quarterly Report, 1 Oct.-31 Dec. 1963

Jan. 1964 95 p refs

(Contract DA-36-039-AMC-03199(E))

(EB-5296-0359-2; AD-435883)

A survey was made of a number of possible uses of the facility including transmission lines, microwave components, lasers, and radiation weapons. A projection of technology for transmission lines for the 1967 to 1977 decade is also included. Power levels of the magnitude anticipated for this period indicate a radical departure from conventional transmission line. The use of high dielectric gases or vacuum will not be sufficient to achieve the required power using conventional waveguide. It presently appears that tall or square waveguide presents an interim solution. However, as research on circular waveguide advances and as power sources for TE₀₁ circular electric mode becomes available, the many desirable features of circular guide will require its use. Delineation of the facility configuration was continued, and a description of the auxiliary equipment needed for the facility is included in this report. Analysis of the high-voltage power supply and high-power modulators was begun. Preliminary results are presented.

Author

N64-24092 Harry Diamond Labs., Washington, D.C.

PROTECTION OF THE HUMAN EYE FROM LASER RADIATION

Harold W. Straub 10 Jul. 1963 11 p refs

(TR-1153; AD-436705)

Various possibilities for protecting the human eye from blinding through laser radiation were considered. Of the investigated selectively absorptive and/or selectively reflective (dielectric) optical filters, some have to be disregarded for a variety of reasons. The Schott BG-18 type filter glass, in a thickness of approximately 4.3 mm, appears to provide adequate protection in the low and medium energy pulse range and in a spectral range between 0.69 and 1.2 μ , covering the ruby as well as the Nd-doped glass and Ca WO₄ lasers. The calculations are based on the assumption of equality of the burn sensitivities of the human and of the rabbit retina. Author

N64-24103* Varian Associates, Beverly, Mass.

MEASUREMENTS AND IMPROVEMENTS OF TWO HYDROGEN MASERS Quarterly Progress Report, Dec. 1, 1963-Feb. 29 1964

R. Vessot 15 May 1964 7 p ref

(Contract NAS8-2604)

(NASA-CR-56549) OTS: \$1.10 ph

This report is concerned with modifying two atomic masers, studying a solid dielectric spherical cavity, and establishing a system to make short-term measurements. According to the theory of the hydrogen maser, the amplitude fluctuations are suppressed and approach zero with increasing radiating power. It should be possible to measure the receiver noise contributions alone when the signals are in phase and to measure the contribution of the phase fluctuations when the signals are in quadrature.

J.R.C.

N64-24108* Varian Associates, Beverly, Mass.

MEASUREMENTS AND IMPROVEMENTS OF TWO HYDROGEN MASERS Quarterly Progress Report, 1 Sep.-30 Nov. 1963

R. Vessot 15 Jan. 1964 14 p refs

(Contract NAS8-2604)

(NASA-CR-56550) OTS: \$1.60 ph

Described is a measurement program for long- and short-term stability, using three hydrogen masers. Measurements to determine the precision to which a given pair of masers can be reset with respect to frequency are discussed. The status of improvements to the masers is given.

G.D.B.

N64-24310 Naval Ordnance Test Station, China Lake, Calif. Michelson Laboratory

REFLECTING PROPERTIES OF AIRCRAFT MATERIALS AT 0.6943 AND 1.06 MICRONS USING PULSED LASERS

Stephen E. Barber *In* AFSC, Griffiss AFB, N.Y. Symp on Radar Reflectivity Meas. Apr. 1964 p 375-381 (See N64-24281 17-15)

The reflectivity of aircraft materials when illuminated by light at 0.6943 μ and 1.06 μ wavelength is discussed. Quantitative results of the return at different angles and the absolute reflectance are given. In addition, some work on optical cross-section measurements is discussed.

Author

N64-24331 Harry Diamond Labs., Washington, D.C.

RANGEMETER FOR XM23 RANGEFINDER

Ira R. Marcus 17 Feb. 1964 46 p refs

(HDL-TR-1199)

The rangemeter is a digital time-interval counter that displays range when coupled to the XM23 Laser Rangefinder. It receives start and stop pulses from the rangefinder and displays range readings from 200 to 9,995 m. The total volume of the rangemeter is less than 18³ in. The readout is made of electroluminescent material, and optical coupling is used between the computing circuits and the photoconductive readout matrix.

Author

N64-24349 General Electric Co., Syracuse, N.Y. Electronics Lab

SEMICONDUCTOR LASER AMPLIFIER TECHNIQUES (SEMLAM)

Griffiss AFB, N.Y., RADC, May 1964 37 p refs

(Contract AF 30(602)-3111)

(RADC-TDR-64-148; AD-601612)

Preliminary tests were started on the overall amplifier system, which includes an oxygen gas laser as an oscillator and GaAs laser diodes as an amplifier with the associated optical components and cryogenic dewar. The emphasis is to construct pulsed and CW GaAs laser diodes with SiO antireflection coatings.

Author

N64-25036 Rochester U., N.Y. Inst. of Optics

THE CONSTRUCTION OF A HELIUM-NEON VISIBLE LASER

Douglas C. Sinclair [1963] 13 p

(Contract DA-ARO(D)-31-124-G139)

(AD-437650)

This report is intended to describe the constructional details of a helium-neon visible (6,328 Å) laser. The description covers the optical, vacuum, and electrical aspects of the construction. The operation of the laser is also described, and a figure included that shows some patterns obtained from the laser.

Author

N64-25090 Radio Corp. of America, Princeton, N.J. RCA Labs.

SOLID STATE LASER EXPLORATIONS Interim Engineering Report, Oct. 15, 1963-Jan. 15, 1964

Z. J. Kiss, R. J. Pressley, F. Sterzer, T. Walsh, and J. P. Wittke Wright-Patterson, AFB, Ohio, Aeron. Systems Div., 1 Feb. 1964 49 p refs
(Contract AF 33(615)-1096)
(IER-1: AD-435158)

Studies of the excitation of trivalent rare-earth ion lasers by crosspumping in absorption bands associated with color centers in the host crystal were made using ErOF-CaF₂. These indicate considerable promise for laser action. Hosts presenting a site of noncubic symmetry for the fluorescent ions were also investigated, including SrCl₂ and various halofluorides. Such hosts have strong fluorescent transitions of the electric dipole type, and several show strong fluorescence at room temperature. SrCl₂, however, shows a strong tendency to cleave under thermal stress. A method of chemically reducing trivalent dysprosium to the divalent state was found and will be exploited in the future. The variation of wavelength and line width with temperature in CaF₂:Dy²⁺ was determined, and this information was applied to several problems concerning laser operation. Frequency shifts of fluorescence and laser output with excitation level were correlated with thermal tuning effects, and threshold measurements with part of the laser crystal shielded were used to gain insight into basic processes. Beam powers of from three to six times normal were obtained by the use of dielectric film reflectors. Lamp efficiencies were also studied, leading to insight into optimum operating conditions. Magnetic effects in CaF₂:Dy²⁺ lasers were studied using various coil configurations. Magnetic modulation is readily obtainable up to 100 kc/sec, and the natural spiking can be synchronized at frequencies well above this, to at least 475 kc/sec. Preliminary laser amplifier studies have been made that indicate gains of greater than 2/in. should be obtainable. Losses at microwave frequencies have been measured in various electro-optic crystals. A variable-bandwidth, cavity-type, microwave-frequency light modulator was designed and is under construction. The detailed theory of the electro optic effect in tetragonal crystals of the KDP type was worked out for an arbitrary direction of the electric field with respect to the crystal axes. Several semiconductor diode detectors were constructed, having response past the dysprosium laser wavelength at 2.36μ. These detectors have a response (rise and decay) time of less than 20 nanoseconds, and a sensitivity that is only three times less than the comparable commercially available units having a much slower response.

Author

N64-25120 Naval Ordnance Test Station, China Lake, Calif.
FLUORESCENCE PUMPING OF LASERS Technical Progress Report 356

Julian L. Thompson Apr. 1964 15 p
(NOTS-TP-3506)

As a part of a continuing program of laser efficiency improvement studies, a preliminary investigation has been made of the feasibility of converting the energy from an essentially white light source into useful pumping wavelengths by means of fluorescence. Both fluorescent dye solutions and powdered phosphors have been considered, and a laser head of coaxial design has been constructed that will enable an experimental study to be made of the use of either, or a combination of both, in modifying the light from an electronic discharge tube. Geometrical design of the optical coupling between lamp and laser rod also comes under study in the search for the ultimate design for the maximum conversion of electrical energy input into coherent light output.

Author

N64-25232 Technical Operations Research, Burlington, Mass.
CONTACT PRINTING WITH COHERENT LIGHT Final Report
H. Heckscher and B. J. Thompson Griffiss AFB, N.Y., RADC,
May 1964 50 p refs
(Contract AF 30(602)-3139)
(RADC-TDR 64-120: AD-602246)

The high degree of collimation and the high energy densities that can be simultaneously obtained from the output of a laser made it an attractive proposition as a light source in contact printers. However, special problems do arise in such a system mainly from the high degree of spatial and time coherence of the laser output. These properties cause deleterious interference and diffraction effects in many printing systems. Experiments are described using an He-Ne gas laser as a light source associated with standard printing frames and continuous drum printers. The troublesome effects, particularly the interference fringes, are illustrated, and a method is shown for eliminating these effects through the introduction of a suitable liquid between the emulsions. Recommendations are made for a feasibility study with improved optical equipment to obtain high resolution, experimenting with Kalvar and diazo-type materials using the nitrogen gas laser as a source, experimenting with the diazo-type material recently sensitized in the green region of the visible spectrum, and more intensive study of the effect of coherence upon exposure.

Author

N64-25319 Columbia U., New York, N.Y. Columbia Radiation Lab.

RESEARCH INVESTIGATION DIRECTED TOWARD EXTENDING THE USEFUL RANGE OF THE ELECTROMAGNETIC SPECTRUM Fifth Quarterly Progress Report, 16 Dec. 1963-15 Mar. 1964

R. Novick 15 Mar. 1964 65 p refs
(Contract DA-36-039-SC-90789)
(CU-3-64-SC-90789: AD-439695)

Further studies were made of the two-photon decay of the metastable helium ion. Precise values have been obtained for the hyperfine interaction constants in the (3d⁵4p)⁷P_{2,4} states of Cr⁵³. Polarization and excitation studies are continuing on the (1s 2p)³P - (1s 2s)³S transition in LiI preliminary to the determination of the ³P fine structure. Improved detectors are being developed for the study of metastable autoionizing atomic states. Work is being resumed on the determination of the fine and hyperfine structure of the 3P term of LiI. Light sources and resonance cells are being developed for double-resonance spectroscopy in the radioactive isotopes of lead and copper. Precise measurements have been made of the hyperfine structure of the 3₁₃ - 3₀₃ rotational transition in NH₂D. A new program of molecular magnetic rotation spectroscopy was undertaken for the analysis of the vibrational structure of selected molecules. Work was resumed on the experiment designed to determine the interaction between free atoms and crystalline surfaces. A detailed ENDOR study of the V_K center in LiF has been completed. A discussion and interpretation are given of the angular dependence of the ENDOR lines arising from this center. The optical-maser-heterodyne spectrometer is being applied to problems in critical opalescence, fluid flow, and birefringence. A HgII green laser is being constructed for use on these experiments. Studies are being made of the fluorescence of a ruby crystal following excitation by ruby-laser light. The results of these studies will be useful in determining the feasibility of the proposed photon-echo experiment.

Author

N64-25515 Dayton U., Ohio Research Inst.
INVESTIGATION OF LASER BEAM CROSS-SECTION WITH RESPECT TO INTENSITY AND TIME Quarterly Progress Report, 1 Jan.-31 Mar. 1963

Werner Rambauske and Michael K. Barnoski [1963] 49 p
(Contract AF 33(657)-9014)
(QPR-3; AD-602525)

The multimode nature of the laser cavity suggests that the beam consists of discrete, optical components separated by a definite interval $\Delta\lambda$, where λ is the wavelength in Å. The photodetectors used to detect this radiation will thus act as photomixers and heterodyne the various modes that, due to the nature of laser cavity emission, already seem to be pulse amplitude modulated. In the course of the investigations it was discovered that no two points in the beam's crosssection displayed the same intensity versus time variation. These results were obtained by utilizing two identical detection systems positioned at various points in the beam's crosssection. Photographic recording of the dual beam scope traces are included in the report. In addition to this, the average intensity over a 50 μ sec interval versus lateral distance through the beam was determined, and the results were plotted. A bell-shaped curve was obtained. Author

N64-25755 Cutler-Hammer, Inc., Deer Park, N.Y. Airborne Instruments Lab.

STUDY OF SOLID-STATE AND TRAVELING-WAVE MASER TECHNIQUES Technical Documentary Report

J. A. De Gruyl, W. W. Heinz, S. Okwit, and J. G. Smith Griffiss AFB, N.Y., RADC, Jun. 1964 13 p refs
(Contract AF 30(602)-2989)
(RADC-TDR-64-226; AD-602437)

The purpose of this program is to develop improved maser techniques and apply them to an operable breadboard maser system. Improved techniques for obtaining the required field gradients were developed, and instantaneous bandwidths greater than 300 mc were obtained using them. In addition, the feasibility of obtaining 500-mc instantaneous bandwidths was shown. Author

N64-25965 Grumman Aircraft Engineering Corp., Bethpage, N.Y. Research Dept.

REQUIREMENT FOR BREWSTER ANGLE WINDOW FOR LOW GAIN LASING SYSTEM

K. G. Leib Feb. 1964 8 p ref
(RN-177)

In many gas laser systems, the requirements on the Brewster angle output windows are quite modest because of the high gain of the system. When the gain is a fraction of a percent, these requirements become more stringent. This report summarizes the calculation for small deviations from the Brewster angle for a number of materials. G. D. B.

N64-26081* National Aeronautics and Space Administration, Ames Research Center, Moffett Field, Calif.

MOMENTUM TRANSFER AND CRATERING EFFECTS PRODUCED BY GIANT LASER PULSES

Frank Neuman Repr. from Appl. Phys. Letters, v. 4, no. 9, 1 May 1964 3 p refs
(NASA-RP-267)

The momentum transfer and cratering effects caused by impacts of focused laser light on the surfaces of several metals are presented. Laser pulse energy measurements were obtained by three independent instruments: (1) a commercial integrating photodiode calorimeter; (2) a blackbody calorimeter; and (3) the momentum transducer. The results indicate that the momenta produced by normal laser pulses strongly depend on the thermal properties of the target material. For the materials tested, the momentum ratio is closely proportional to the product of the relative melting point and to the thermal conductivity. J. L. D.

N64-26173 Army Signal Research and Development Agency and Lab., Fort Monmouth, N.J.

ENGINEERING TEST OF X-BAND MASER FOR WEATHER RADAR SET AN/MPS-34

Raymond L. Robbani Mar. 1964 34 p
(USAE LRDL-TR-2427; AD-602141)

An engineering test was performed to determine the increase in sensitivity that an X-band helium maser could afford a Radar Set AN/MPS-34. The maser increased sensitivity by 12.5 db. Radar sensitivity improvement suggests many prospects for future uses in nuclear-weather surveillance. These include improved meteorological intelligence and satellite operations. Future plans are explored. Photographs show a comparison in storm detection of Radar Set AN/MPS-34 with and without maser amplification. Author

N64-26264 Lincoln Lab., Mass. Inst. of Tech., Lexington
SOLID STATE Division 8 Quarterly Progress Report, 1 Jan.-31 Mar. 1964

Alan L. Mc Whorter and Peter E. Tannenwald 5 May 1964
17 p refs
(Contract AF 19(628)-500)
(ESD-TDR-64-47; AD-439365)

The current status in the following areas is discussed: (1) solid-state device research, with emphasis on diode lasers; (2) laser research, with emphasis on Raman emission; (3) materials research, with emphasis on growing refractory crystals; (4) band structure and spectroscopy of solids (Bi, Sb, and HgSe); and (5) magnetism and resonance, with emphasis on Heisenberg exchange in the molecular-field approximation. I. v. L.

N64-26302 Technical Research Group, Inc., Melville, N.Y.
RESEARCH ON PROPERTIES OF LASER DEVICES Eighth Quarterly Technical Summary Report, 1 Mar.-31 May 1964

R. Kaplan, ed. [1964] 75 p refs
(Contract AF 49(638)-673; ARPA Order 256-62; Proj. Defender)
(TRG-134-QTR-8; AD-443700)

The rate equations have been solved to yield the level populations in collision-relaxed laser media; machine computations involving as many as 43 levels in Mn and La predict inversions in steady-state discharges. An Al_2O_3 tube for vaporizing Mn has been rebuilt using Al_2O_3 sand as insulation. The experimental implementation of a photodissociation laser has continued; the effect of heat induced turbulence and convection within the optical resonator has been largely eliminated. The development of a nuclear-pumped solid-state laser has continued. A 90% increase in the single-mode power and efficiency of a gas laser has been achieved by diffraction coupling of the output around a small spot reflector; mode selection was achieved without increasing alignment tolerances; and a computation of diffraction effects in cavities having low Fresnel numbers was carried out. Author

N64-26652 American Optical Co., Southbridge, Mass. Research Center

EXPERIMENTAL VERIFICATION OF SUN POWERED LASER TRANSMITTER Interim Engineering Report No. 2, Aug.-Nov. 1962

D. A. La Marre, G. R. Simpson, and M. R. Thorburn [1962]
41 p refs
(Contract AF 33(657)-8619)
(IER-2, AD-437864)

The continuing effort of experimentation and design leading to the delivery of an experimental model of a sun-powered

laser transmitter is described. The design and fabrication of the transmitter is discussed with respect to the optical system and mount. An experimental Nd-doped CaWO_4 laser is described. Related to this description are integral pump optics requirements, fabrication problems, and thermal considerations of the unit. Experimental Nd-doped glass lasers are discussed in both the short- and long-fiber configurations. Author

N64-26667* Hughes Aircraft Co., El Segundo, Calif.
DEEP SPACE OPTICAL COMMUNICATIONS SYSTEMS STUDY

Washington, NASA, Jul. 1964 232 p refs Previously Published as NASA-CR-56466, see N64 2244/ 15-08) (Contract NAS9-879) (NASA-CR-73, NASA-CR-56466) OTS: \$3.50

The feasibility and desirability of using the laser and suitable optical detectors in a communication system that will provide two-way telemetry, voice, and down-TV from distances of the order of 50 million miles were studied. The problems in the practical utilization of the detectors in a laser communication system are discussed and operating problems of numerous lasers are characterized. The statistical nature of the noise from the various lasers (i.e., its coherence and stability properties) are examined, and various types of modulation systems are discussed. The properties of various physical devices and their effective utilization in light modulation are discussed. Various demodulation systems are outlined, and a theoretical comparison is made to establish a performance characterization as a function of frequency, bandwidth, and external noise. The effects of attenuation and external noise sources on system performance are established, the optimum operating frequency selection and the source destination selection are also established. P V L

N64-26674 American Optical Co., Southbridge, Mass. Research Center

EXPERIMENTAL VERIFICATION OF SUN-POWERED LASER TRANSMITTER Interim Engineering Report No. 1 D. A. LaMarre [1962] 43 p refs (Contract AF 33(657)-8619) (AD-437865)

The feasibility of using four-level laser materials is investigated. A general expression is derived for the figure of merit "G" of a four-level laser in the sun-powered end-pumped configuration. ("G" relates the laser parameters to the power input needed for threshold lasing). In a survey of possible new laser materials, two four-level types, neodymium-doped calcium tungstate and neodymium-doped glass, were determined to be promising. Thermal problems involved in cooling neodymium-doped glass are analyzed. The status of the design and construction of the sun-tracking laser mount is specified. Author

N64-26933 Air Force Systems Command, Wright Patterson AFB, Ohio Foreign Technology Div
THE MOON UNDER KLI EGLIGHTS

Herbert Pfaffe 4 May 1964 5 p Transl into ENGLISH from Berliner Zeitung (E. Berlin), 5 Apr. 1963 p 5 (FTD TT-64 336/ 1, AD 600508)

A method for moon observation based on the use of laser optics is presented. It provides for the generation of short, very high energy light pulses directed toward the moon. With this technique, regions of the moon can be irradiated with artificial light in the visible spectral range, so that this "spot-light type" illumination can be seen from the earth. This new method makes possible the success of future manned lunar landing because of the added knowledge of the composition of the moon's surface. A L B.

N64-27290* Texas A&M U., College Station
THE SCATTERING OF PULSED LASER LIGHT FROM PLASMAS

Melvin Eisner [1964] 13 p (Grant NsG-239-62, Proj. No. 4) (NASA-CR-56889) OTS: \$1.60 ph

The availability of intense monochromatic sources provided by pulsed lasers makes it possible to attempt observation of both the angular distribution and spectral distribution of laser light scattered from plasmas of relatively modest densities and temperatures. Scattering theory is discussed. The design of an experiment to study free particle-scattering modes is presented, and a steady-state experiment being conducted in an attempt to observe the electron velocity distribution in a plasma produced by an RF discharge is discussed. R.T.K.

N64-27473 Air Force Cambridge Research Labs., Bedford, Mass.

A STUDY OF TRANSVERSE MODES OF RUBY LASERS USING BEAT FREQUENCY DETECTION AND FAST PHOTOGRAPHY

C. Martin Stickley (Ph.D. Thesis-Northwestern U.) May 1964 88 p refs *Its Phys. Sci. Res. Papers No. 19* (AFCLR-64-434, AD-603594)

Intensity variations in the frequency range of 6 to 141 mcps have been detected in the output of ruby lasers. These are interpreted to be beats between simultaneously occurring transverse modes with the same axial mode number, rather than beats between two modes in regions of the ruby rod having slightly different path lengths. Evidence for this interpretation was provided primarily by two experiments: (1) The beats disappeared when the ruby laser rod was operated with small mirrors (2) Streak photographs of a narrow strip of the end of the rod always showed a phase variation across the rod of the beat frequency. A review of laser resonator theory is given. Extensive measurements of a ruby rod whose path length variations were approximately $\lambda/10$ showed that the transverse modes and beat frequencies were characteristic of a nonconfocal resonator rather than a plane-parallel resonator. Author

N64-27562 United Aircraft Corp., East Hartford, Conn. Research Labs.

RESEARCH ON THE ELECTRICAL BREAKDOWN OF GASES UNDER INTENSE OPTICAL ILLUMINATION Final Report, Aug. 1, 1963-Jan. 30, 1964

R. G. Meyerand, Jr., and A. F. Haught 27 Jan. 1964 23 p refs (Contract Nonr-4299(00); ARPA Order 306; Proj. Defender) (C-920088-2; AD-428206)

A theoretical and experimental research program was conducted on the physical mechanisms associated with the electrical breakdown of gases under the intense optical illumination from a laser. The light beam from a ruby laser was focused to a small region in the center of a test cell to ionize helium, argon, and air. Breakdown in air required the highest field strengths, the next highest were required to ionize helium, and the lowest field strengths were required for argon. Theoretical studies indicated that the inverse bremsstrahlung process, involving the absorption of optical photons by free electrons during collisions with gas atoms, satisfactorily accounts for the high degree of ionization produced during the short laser pulse and, in addition, predicts the observed pressure dependence of the breakdown. It was observed that as much as 50% of the total energy in the laser beam was absorbed in the plasma produced by breakdown and attenuations by as much as a factor of 10 were observed in the intensity of the laser beam at later times in the optical pulse.

An extension of inverse bremsstrahlung to the fully ionized case shows considerable promise as the process to account for this absorption. Author

N64-27737 Stanford U., Calif. Microwave Lab.
MICROWAVE RESEARCH Quarterly Status Report No. 21, 1 Feb.-31 Apr. 1964

C. F. Quate et al Jul. 1964 15 p ref
(Contract Nonr 225(48))
(ML-1192; AD-602967)

Reports are made on studies of the microwave region of acoustic wave amplification in piezoelectric semiconductors, the improvement and extension of the performance of optical masers, nonlinear microwave propagation in gyromagnetic media, diffraction of light waves by hypersound, and the force configuration on electrically neutral bodies in the presence of electromagnetic fields produced by high laser beams. A.W.

N64-27998 Utah U., Salt Lake City Microwave Devices Lab.
QUANTUM STUDIES

V. R. Johnson, R. W. Grow et al *In its Consolidated Quart. Rept.*, Jan. 1-31 Mar. 1964 31 Mar. 1964 p 33-67 refs
(See N64-27996 23-20)

1. IRRADIATED LASER MATERIALS V. R. Johnson and R. W. Grow p 33-60 refs
2. TUNNELING STUDIES M. D. Crawford and R. W. Grow p 60-62
3. MILLIMETER WAVE MASERS J. C. Clark and R. W. Grow p 62-64 refs
4. GAS LASER STUDIES S. C. Carr, M. H. Dittmore, and R. W. Grow p 65-67

N64-28144 Spectrolab, Inc., Sylmar, Calif.
DESIGN AND FABRICATION OF OPTICAL FILTERS FOR LASER FREQUENCY Quarterly Progress Report No. 2, 10 May-9 Aug. 1963

Samuel J. Holmes and Noel Bowman 29 Aug. 1963 14 p
(Contract AF 33(657)-9216)
(QPR-2; AD-419554)

The spectral transmission of Indian ruby and of Indian clear-green mica is presented. The Indian ruby mica cleaves with good uniformity and flatness, but the absorption factor significantly limits the transmission efficiency of the mica filter. The Indian clear-green mica shows far less absorption than the Indian ruby mica, but does not cleave with the relatively large uniformity areas as desired. Some promising results were obtained in an experimental effort to reduce the absorption of the Indian ruby mica. R.T.K.

N64-28283 Eastman Kodak Co., Rochester, N.Y. Apparatus and Optical Div.
LASER MATERIALS STUDY Semi-Annual Technical Report, 1 Jul.-31 Dec. 1963

P. B. Mauer [1963] 6 p
(Contract NONr-3834(00); Proj. Defender)
(AD-442059)

Considerable time was spent in adapting the glass-plant procedures to handle silicated glass formulations of a sufficient size to give good optical quality. The in-house capability to provide a low-melting lithium silicate glass as a second comparison for the standard borate material was extended. This glass was cast, annealed, ground and polished, but it was not coated and tested. R.T.K.

N64-28526 Army Signal Research and Development Agency and Lab., Fort Monmouth, N.J.

REFLECTIVE TYPE LASER AMPLIFIER

H. Jacobs, D. A. Holmes, L. Hatkin, and F. A. Brand Jun. 1964 21 p
(TR-2467; AD-604100)

Calculations were carried out in an analysis of a reflection-type laser amplifier. Electromagnetic radiation is assumed to travel at normal incidence through a system composed of air, a partially transmitting silver reflector, active media such as ruby, and a thick silver reflector. The analysis is facilitated by considering the ruby as a medium with an effective negative conductivity resulting in the growth of the wave during propagation. Highest gains are obtained with the front mirror completely removed, since losses resulting from a skin effect mechanism cut down the useful power output. In the system consisting of air, ruby, and metal, the presence of the rear metal reflector decreases the angle required for maximum gain to almost half the value required for a completely transmitting system consisting of air, ruby, and air. Author

N64-28550 Hughes Research Labs., Malibu, Calif.
LASER DEVICES EXPLORATORY INVESTIGATION Interim Engineering Report, 1 May 1964-31 Jul. 1964

H. V. Winston [1964] 28 p refs
(Contract AF 33(657)-11650)
(IER-5; AD-604038)

Quarter-wave plates for a longitudinal mode selector were completed. Evaluation of a liquid-nitrogen-cooled pumping configuration for ruby showed that the overall efficiency is lower than for a room-temperature system despite a 40% lowering of threshold. Therefore, attention was given to the further improvement of noncryogenic systems, including the effects of multiple ellipse cavities, improved optical finish, and cooling to 0° C. The efficiencies of several useful linear flash lamps were measured. Equipment for the growth of yttrium oxide was modified and is ready for operation. Doped lanthanum fluoride of excellent optical quality was prepared and used for optical and microwave studies. Improvements in the mode control of giant pulse lasers have resulted in significant changes in the anti-Stokes emission in benzene, when produced by essentially single-mode ruby radiation, the anti-Stokes line is sharp in wavelength and angle, and the angle corresponds to the requirements of index matching. Thresholds and conversion efficiencies for the production of stimulated Raman scattering were measured, and the production of damage in transparent dielectric materials was investigated. Author

N64-28577 National Co., Inc., Malden, Mass.
INVESTIGATION OF MULTIPLE SPIN FLIP PROCESSES TO PRODUCE TRANSITIONS AND INVERSIONS AT ARBITRARY FREQUENCIES Final Report

George W. Myers 16 Mar. 1964 72 p refs
(Contract AF 19(628)-456)
(AFCRL-64-243; AD-603553)

The rate equations governing the operation of a six-level maser using cross relaxations between the three pairs of spin levels in phosphorous-boron doped silicon are derived. Excess populations are obtained under the assumption that the longitudinal relaxation time for electrons in boron states is much shorter than that for electrons in phosphorous states, in terms of a cross relaxation time τ_x and the longitudinal times τ_1 . Dependence of τ_x on concentrations, and minimal conditions for inversion, are established. The criteria for the design and operation of a dual-mode spectrometer to be used to measure τ_x and as a maser, are established in terms of microwave parameters and spin system-crystal parameters.

Estimates of the operating values are made by taking reasonable values for the parameters. The final design and operation of the spectrometer are described. The effects of cavity loading are estimated in terms of the cavity mode and crystal lossiness, and are compared to the experimental practice. Sensitivity of the spectrometer and experimental results are given.

Author

N64-28579 General Electric Co., Schenectady, N.Y. Research Lab.

SEMICONDUCTOR DEVICE CONCEPTS Scientific Report No. 7

H. H. Woodbury, M. Aven, F. K. Heumann, and R. N. Hall 5 May 1964 61 p refs

(Contract AF 19(628)-329)

(AFCR-64-467; AD-603783)

Studies of the defect chemistry of the II to VI compounds were continued, and a comparison is made of the electrical behavior of CdTe, CdS, and ZnSe following either thermal firings or 1.5 Mev electron bombardment. A common double-acceptor center is identified and is postulated to be an anion vacancy-halogen impurity complex. The diffusion of Cu into undoped ZnS as well as Cl-doped and Al-doped ZnSe was investigated by radiotracer techniques. The results were used to correlate the electrical and optical activity of some defect centers in II to VI compounds. The implication of the findings on the mechanism of electron-hole recombination in ZnSe-Cu₂Se heterojunctions was discussed. The halogen transport growth of GaAs_xP_{1-x} crystals continued. Laser quality material is being produced, but the ingots, while relatively homogeneous, are polycrystalline. Several ingots of GaAs and GaAs_xP_{1-x} were made using a lower furnace temperature. These ingots have large single-crystal regions and are more homogeneously doped than previous ones. Exciton and related luminescence phenomena that occur near the band edge of a semiconductor are discussed and compared with the absorption spectrum.

Author

N64-28645 Westinghouse Electric Corp., Baltimore, Md. Aerospace Div.

DEVELOPMENT OF MILLIMETER AND SUBMILLIMETER MASER DEVICES Interim Technical Report, 1 Feb.-31 May 1964

W. E. Hughes [1964] 20 p ref

(Contract AF 33(657)-10472)

(ITR-4; AD-602019)

A zero-magnetic-field maser was operated at a frequency of 81.3 Gc with the iron ion in rutile, a zero-magnetic-field maser was operated at a frequency of 78 Gc with the iron ion in zinc tungstate, and the first reported paramagnetic resonance absorption was observed at frequencies near 330 Gc with the manganese ion Mn³⁺ in rutile.

Author

N64-28754* Rice U., Houston, Tex.

ZEEMAN EFFECT AND RUBY LASER POLARIZATION

A. S. Badger and T. A. Rabson [1964] 7 p refs Submitted for Publication

(Grant NSG-6-59)

(NASA-CR-58358) OTS \$1.10 ph

An investigation of the possibility of accomplishing polarization control in a solid-state laser by subjecting the lasing medium to a controllable magnetic field is reported. The results showed no change in the polarization of the output of a ruby laser for uniform fields perpendicular to the axis of the laser with magnitudes up to 8,000 gauss for either the 0° rod

or the 90° rod. The effect of magnetic fields on the microwave beats in the output of a ruby laser was also investigated. The only reproducible effect observed was that the amplitude of the microwave beating was considerably reduced by the application of a magnetic field of sufficient intensity to counteract the magnetic field produced by the exciting current in the linear flash tube. Work is continuing on other solid-state materials not having a powerful crystal field as does ruby.

M. P. G.

N64-28835* General Dynamics/Electronics, Rochester, N.Y. Research Dept.

LASER MODULATION AT THE ATOMIC LEVEL Monthly Report, 17 Jul.-31 Jul. 1964

E. G. Brock, F. C. Unterleitner, Y. C. Kiang, and J. F. Stephany 10 Aug. 1964 9 p

(Contract NASw-1008)

(NASA-CR-58627; MR-1) OTS: \$1.10 ph

This report describes the effort devoted to preparations for the experimental determination of the absolute value of optical gain in ruby lasers as a function of inhomogeneous magnetic-field intensity. The approach that was chosen for measuring the dependence of gain on the magnetic field uses the threshold for laser oscillation as the criterion for showing that a gain sufficient to overcome cavity losses has been achieved. The cavity in which the laser crystal is optically pumped and subjected to a magnetic field, the optical bench for making the transmission measurements, and the positioning of the collimated probe beam are described. Electronic circuitry permits the magnetic field and the flash lamp and probing lamp of the optical bench to be pulsed in the desired frequency.

I. v. L.

N64-28881* Varian Associates, Beverly, Mass.

HYDROGEN MASER PROGRAM Interim Technical Report, 1 Feb. 1962-31 May 1963

R. Vessor 30 Jan. 1964 82 p refs

(Contract NAS8-2604)

(NASA-CR-58525) OTS: \$8.10 ph

The hydrogen maser is the result of a search for a new type of maser operating between two hyperfine levels in one of the hydrogen-like atoms. This report describes the design and development of its various components. These include: (1) the frame and vacuum manifold, (2) the hydrogen purifier and flow control, (3) the magnetic hexapole state selector, (4) the hydrogen storage bulb, (5) the RF cavity, and (6) magnetic shielding and field controls. In addition, data are reported from measurements of the relative stability of two masers as well as on their stability as measured via external communications.

I. v. L.

N64-29051 Radio Corp. of America, Camden, N.J. Defense Electronic Products

DOPPLER OPTICAL NAVIGATOR First Quarterly Progress Report

W. J. Hannan, L. J. Nicastro, and C. W. Reno 19 Sept. 1963 63 p refs

(Contract AF 33(657)-11458)

(QPR-1; AD-420000)

Analysis of overall performance of the doppler optical navigation system, taking into account solar background noise, atmospheric attenuation and typical operational requirements, leads to the conclusion that required transmitter power is considerably greater than the power available from currently available lasers. Developments that promise to reduce required transmitter power are described. The "coherence" gain afforded by amplitude modulation of the optical carrier wave is also

analyzed. It is concluded that amplitude modulation not only simplifies the doppler detection circuits but also increases the fractional intensity of the doppler signal component. Measured stability of the He-Ne gas laser indicates that it is just about stable enough to provide a velocity measurement accuracy of 5 m/sec. Author

N64-29284 Sperry Gyroscope Co., Great Neck, N.Y. Electro-Optics Group
ELECTROMAGNETIC ANGULAR ROTATION SENSING Interim Engineering Report No. 1, 1 Jun.-31 Aug. 1963
 D. Davis, W. Macek, R. Schneider, and G. White Sep. 1963 47 p
 (Contract AF 33(657)-11433)
 (AB-1108-0016-1; AD-418588)

Studies have been conducted on adapting the Sperry ring laser for rotation sensing. The investigations have been conducted at three different wavelengths—0.6328 μ , 1.153 μ , and 3.39 μ —using the He-Ne gas system. Although higher gain is realized at 3.39 μ and increased sensitivity at 0.6328 μ , it appears that the 1.153 μ laser is more suitable for experimental evaluation because of superior stability. Consequently, the more practical Faraday biasing technique is currently being designed for the 1.153 μ system. Improvement of an order of magnitude has resulted from an alternate optical combiner, which inherently reduces energy coupling from one traveling-wave mode to the other. All results are in keeping with the qualitative hole-burning theory and nonlinear oscillation model that is discussed. Author

N64-29382 MHD Research, Inc., Newport Beach, Calif.
HIGH POWER LASER PHYSICS. PART A: ON THE PHYSICAL THEORY OF LIQUID LASERS. PART B: NUCLEAR PUMPING OF SEMICONDUCTOR LASERS Final Report
 Francis H. Webb, Jr., Paul Thiene, Paul Levine, and Joseph Eerkens (Terra Nova, Inc.) Nov. 1963 162 p ref
 (Contract Nonr-4124(00); Proj. Defender)
 (MHD-645; AD-423718)

A theoretical investigation was made of two possible high-power laser concepts—one, an investigation of liquid lasers, and the other, an investigation of the nuclear pumping of semiconductors. Both gain and loss processes in liquid lasers were considered. These include stimulated emission and losses due to refraction, absorption, scattering, and refraction. Two rare-earth doped halide systems were investigated. One system considered employs AsCl₃(UCl₃); here an optimum threshold power of $Q = 3.77 \text{ w/cm}^3$ was computed, whereas for an AsCl₃(NdCl₃) system, an optimum threshold power of $Q = 1.280 \text{ w/cm}^3$ was determined. The output wavelength should be $\lambda = 2.46\mu$ using uranium, and $\lambda = 1.06\mu$ for neodymium. It appears possible, on the basis of analyses, to achieve laser action by nuclear pumping in bulk direct gap semiconductors. Bulk free-carrier threshold levels are calculated for GaAs. The effects on the threshold due to donor and acceptor levels are also included. High conversion efficiencies appear possible. The degradation of performance due to radiation damage appears to be the major uncertainty. I.v.L.

N64-29401* Varian Associates, Beverly, Mass.
MEASUREMENTS AND IMPROVEMENTS OF TWO HYDROGEN MASERS Quarterly Progress Report, Mar. 1-Jun. 30, 1964

R. Vessot 20 Jul. 1964 12 p
 (Contract NAS8-2604)
 (NASA-CR-58644) OTS: \$1.60 ph

A mounting and tuning mechanism has been built for incorporating a solid cavity into hydrogen masers. A system for phase locking a crystal oscillator to a hydrogen maser for making long-term measurements via VLF and Loran "C" is under construction. A cross-correlation technique for measuring the short term properties of stable oscillators is also presented. P.V.E.

N64-29407* Radio Corp. of America, Princeton, N.J. RCA Labs.
HIGH-EFFICIENCY NARROW-BAND LASER PUMP Final Report, Jan. 24, 1963-Feb. 28, 1964
 S.A. Ochs and J. I. Pankove Huntsville, Ala., NASA, Feb. 1964 38 p refs
 (Contract NAS8-5219)
 (NASA-CR-58645) OTS: \$3.60 ph

The pumping of a CaF₂:Dy²⁺ laser by means of injection luminescence from GaAs_{0.73}P_{0.27} pn junctions was studied. Diodes were made from such an alloy grown epitaxially on (100) GaAs. External conversion efficiencies of about one photon leaving the diode per 100 electrons traversing the junction were obtained. One hundred diodes were connected in series, in ten linear arrays, and were arranged around the laser rod. This assembly was immersed in liquid helium cooled below the lambda point. Single current pulses caused lasing when the total light output of the diodes was about 0.1 watt. An appreciable delay was found between the beginning of the current pulse and the onset of lasing. Heating effects limited the lasing action to about 0.2 second. Author

N64-29420 Lincoln Lab., Mass. Inst. of Tech., Lexington
SOLID STATE RESEARCH, 1964
 4 Jun. 1964 77 p refs
 (Contract AF 19(628)-500)
 (ESD-TDR-64-48; AD-601830)

Activities in the following areas of research are summarized: (1) solid-state device research; (2) laser research; (3) materials research; (4) band structure and spectroscopy of solids; and (5) magnetism and resonance. P.V.E.

N64-29453* National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Md.
A RUTILE TRAVELING WAVE MASER
 C. Curtis Johnson Washington, NASA, Sep. 1964 14 p refs
 (NASA-TN-D-2490) OTS: \$0.50

This paper introduces a new type of traveling wave maser in which the active material is chromium-doped rutile (TiO₂) and the slow wave structure is a meander line. The basic components of a maser, that is, the active material, the slow wave circuit, and the reverse isolation requirements, are discussed. This device has a 10° K noise temperature. Data are presented on the gain realizable over a 250-mc tunable bandwidth. Author

N64-29624 Oak Ridge National Lab., Tenn.
LENGTH-MEASURING LASER INTERFEROMETER
 H. S. Corey, C. M. Lay, R. W. Schede, and R. E. Sladky 18 Sep. 1964 21 p refs
 (Contract W-7405-ENG-26)
 (Y-1466) OTS: \$0.50

A length-measuring interferometer utilizing a continuous laser light source has been successfully used in connection with an inspection machine. Measurements made on a 10-in. gage block demonstrated a combined accuracy and precision

of better than 10μ in. at this distance. Information is also available concerning the method of calculating the precise wavelength of the 6328 Å laser emission. The validity was established by the gage block measurements. Author

N64-29641 International Business Machines Corp., Yorktown Heights, N.Y. Watson Research Center
GaAs LASER MATERIALS STUDY Second Semiannual Technical Summary Report, 1 Jan.-31 May 1964
W. J. Turner and H. Rupprecht [1964] 33 p refs
(Contract Nonr-4136(00); Proj. Defender)
(AD-442598)

In a previous report, observations of crystal defects such as laminar distribution of impurities perpendicular to the growth direction were discussed. In this report, further evidence of these striations from infrared transmission microscopy is presented. The origin of the striae in Czochralski pulled crystals was traced to the uneven motion of the seed holder as a consequence of the magnetic pulling mechanism. In support of the goal of higher power, higher temperature operation, a study of the temperature dependence of laser parameters such as gain per unit length, loss per unit length, and threshold current density was undertaken, and the results are presented. The advantages for ultimate device objectives of different fabrication techniques such as traveling solvent growth, and combined vapor growth and diffusion techniques for p-n⁻ structures are explored. Author

N64-29681 Linde Co., Indianapolis, Ind. Speedway Labs.
SYMMETRICAL LASER CRYSTALS Annual Summary Report, 1 May 1963-30 Apr. 1964
O. H. Nestor 25 Jun. 1964 32 p refs
(Contract Nonr-4131(00); ARPA Order-306-62; Proj. Defender)
(AD-442555)

The objectives of this program are to grow cm^3 -size crystals of cubic perovskites activated with divalent or tetravalent dopant cations, which will substitute directly without charge compensation, and to determine the fluorescence characteristics of these materials. Perovskites of primary and secondary interest are BaZrO_3 and SrTiO_3 , respectively. Cations of interest include divalent and tetravalent rare earths and Mn^{+4} . Several growth techniques were utilized, focusing on BaZrO_3 and SrTiO_3 but also including BaTiO_3 , BaSnO_3 , SrSnO_3 , and SrZrO_3 . Crystalline BaZrO_3 samples, both Sm-doped and undoped, were recovered from solidified melts. Short- and long-lived visible fluorescence was observed in the specimens, but have not been delineated as yet. Large crystals of $\text{SrTiO}_3:\text{Mn}^{+4}$ were grown. Their quality appears to be fair. Submillimeter-size crystals of cubic BaZrO_3 and orthorhombic SrZrO_3 were grown by a flux technique, and millimeter-size crystals of CeO_2 were grown from a flux solution. I.v.L.

N64-29697* Varian Associates, Beverly, Mass.
THE DEVELOPMENT AND CONSTRUCTION OF TWO HYDROGEN MASERS Interim Technical Report, 1 Feb. 1962-31 May 1963
R. Vessot et al 30 Jun. 1964 100 p refs
(Contract NAS8-2604)
(NASA-CR-58542) OTS: \$8.60

The design and development of the various components of the hydrogen maser are described. These include the following: the frame and vacuum manifold, the hydrogen purifier and flow control, the hydrogen discharge dissociator, the magnetic hexapole state selector, the storage bulb, the RF

cavity, and magnetic shielding and field controls. In addition, data are reported from measurements of the relative stability of the two state-of-the-art hydrogen masers, as well as their stability as measured via external communications. A report on the frequency of hydrogen is presented as an appendix. I.v.L.

N64-29835 Calif. Inst. of Tech., Pasadena Quantum Electronics Lab.
LASER ELECTROMAGNETICS Final Report
Nicholas George 1 Jul. 1964 16 p refs
(Contract AF 19(604)-8052)
(AFCRL-64-538; AD-604728)

This program of research in laser electromagnetics includes research into the generation, propagation, and detection of very-high-frequency (optical) coherent electromagnetic radiation. Abstracts of the following reports are included in this report: Light Scattering from Dielectric Film Laser Mirrors, Modified Fabry-Perot Interferometer, Multireflector Optical Resonators, Interferometric Measurement of Index of Refraction, and Plasma Diagnosis by Means of Photon-Electron Scattering. Author

N64-29837 California Inst. of Tech., Pasadena Quantum Electronics Lab.
ROTATIONAL MODES IN SPHERICAL-MIRROR RESONATORS Scientific Report No. 2
Walter A. Specht, Jr. Jun. 1964 44 p refs
(Contract AF 49(638)-1322)
(AFOSR-64-1311; AD-604690)

This work is the examination of a cavity mode approach to the mode structure of a laser. The solution of the vector wave equation for rotational fields in and between oblate spheroidal cavities is examined for the case of wavelengths much less than cavity dimensions. These solutions are rotational field modes in Fabry-Perot-type resonators with equal-radius concave spherical mirrors, or with concave-convex spherical mirrors, when the parameters of the oblate spheroids are chosen so that the radii of curvature and spacing on the axis of rotation match those of the resonator mirrors. Expressions for the transverse and longitudinal rotational mode structures are derived. The eigenvalue equations are written and are solved for the case of the two lowest order modes. Author

N64-29909 Air Force Cambridge Research Labs., Bedford, Mass. Office of Aerospace Research
LASER-SATELLITE REFLECTION PARAMETERS
Robert L. Iliff Jun. 1964 19 p refs /ts Environmental Res. Papers No. 23
(AFCRL-64-475; AD-605270)

Satellites of various configurations are examined as possible laser reflectors. Attention is given to the nature of the reflected signal, atmospheric attenuation, and problems involved in aiming the laser. Nomograms are presented for the determination of the geometric attenuation of the signal as a function of laser divergence, range, target size, receiver aperture, and, where applicable, divergence caused by degraded corner reflector. Author

N64-30135 Rochester U., N.Y. Inst. of Optics
SOME DEMONSTRATION EXPERIMENTS IN OPTICS USING A GAS LASER
David Dutton, M. Parker Givens, and Robert E. Hopkins Oct. 1963 26 p refs
(Grant NSF-G-22941)

Some elementary experiments in geometrical and physical optics, usually limited to individual observations in the laboratory, can be adapted for presentation to larger groups as lecture or classroom demonstrations, by making use of the gas laser as a light source. This paper describes several such experiments dealing with lens aberrations, interference and diffraction phenomena, and the Abbe theory of the microscope, together with some practical optical systems for performing them. Author

N64-30143 Isomet Corp., Palisades Park, N.J.
CRYSTALS FOR OPTICAL MASER APPLICATIONS Final Report, 1 Jul. 1962-30 Jun. 1963 [1963] 25 p (Contract DA-36-039-SC-90876) (AD-438422)

A variety of laser materials including ruby, calcium tungstate, calcium fluoride, strontium titanate, and neodymium glass doped with various rare earths were successfully fabricated into laser rods of various configurations. Author

N64-30159 Varian Associates, Palo Alto, Calif. Central Research Lab.
COHERENT INFRARED LASER Semi-annual Technical Summary Report No. 1, 17 Jun.-16 Dec. 1963 M. W. Muller, A. Sher, and R. Solomon [1963] 69 p refs (Contract Nonr-4244(00); Proj. Defender) (VARIAN-314-15; AD-428562)

This report is concerned with techniques of obtaining population inversions among vibrational energy levels of molecules, with a view to using such inversions for the generation of coherent infrared light. The basis for obtaining population inversions is the Franck-Condon principle, and the first molecule under consideration, to which most of the work so far has been devoted, is half-heavy hydrogen HD. Calculations relevant to the behavior of this molecule and to the properties of hydrogen gas discharges are reported. Theoretical work relating to other molecules is outlined. Author

N64-30170 Radio Corp. of America, Princeton, N.J. RCA Labs.
SOLID STATE LASER EXPLORATIONS Interim Engineering Report, Apr. 16-Jul. 15, 1964 J. Collard, R. C. Duncan, R. J. Pressley, F. Sterzer, T. Walsh et al Wright-Patterson AFB, Ohio, ASD, 1 Aug. 1964 34 p refs (Contract AF 33(615)-1096) (IER-3; AD-603133)

Several hard host materials are being investigated as room-temperature continuous-wave laser possibilities. These include yttrium aluminum garnet, lanthanum aluminate, and calcium molybdate. Stable divalent dysprosium in CaF_2 was obtained by either of two techniques—a chemical reduction or solid-state electrolysis. Laser beam patterns have been measured, and cw lasers were operated using external reflectors. The effects of static, homogeneous magnetic fields on cw $\text{CaF}_2:\text{Dy}^{2+}$ lasers were observed. Pumping lamp efficiencies were studied experimentally, and the results were found to be in good agreement with previously described calculations. Improved methods of keeping laser crystals cold during operation under high excitation conditions were developed and successfully tested. A microwave-frequency cavity modulator was operated with hexamine. The theory of the current-dependence of the junction capacitance of a p-n junction under reverse bias was developed and applied to a set of measurements on a diode made from part of a 2N1309 transistor. Author

N64-30190 Stanford U., Calif. Microwave Lab.
RESEARCH AND INVESTIGATION OF SELECTED MICROWAVE PROBLEMS Interim Engineering Report No. 5, 1 Mar.-31 May 1964 Jul. 1964 14 p refs (Contract AF 33(657)-11042) (ML-1189; AD-443416)

Results are reported for the following continuing studies: (1) nonlinear radiation from plasma oscillations; (2) acoustic wave interactions, including coupling to hypersonic waves, diffraction of light with hypersound, and generation of hypersound with laser light; (3) transverse wave devices involving θ -varying displacement waves rather than space-charge waves for fast-wave interaction with smooth waveguide circuits; (4) optical spectroscopy of laser materials; and (5) nonlinear quantum studies. M.P.G.

N64-30534 International Business Machines Corp., Yorktown Heights, N.Y. Thomas J. Watson Research Center
INJECTION LASER STUDY Quarterly Progress Report, 1 Mar.-31 May 1964 W. P. Dumke, F. Stern, and K. Weiser [1964] 51 p refs (Contract DA-36-039-AMC-02349(E)) (QPR-4; AD-603651)

A fairly comprehensive computer program has been written for studying the gain and loss characteristics of a wide range of laser structures having layers with different optical properties. Calculations for conventional zinc-diffused injection lasers show that a reasonable optical model can fit the observed loss and the far-field angular distribution perpendicular to the junction plane. A new method for fabricating GaAs laser diodes with P-P⁻-N structure has been developed. Switching into the lasing state has been achieved at 77° K in the P-P⁻-N diodes, and from a low-current to a high-current state at room temperature. A theory of the switching speed of P-I-N diodes whose negative resistance arises from light absorbed in the high-resistance region has been given for the limiting cases of high and low external circuit impedance. Author

N64-30590 Columbia U., New York, N.Y. Columbia Radiation Lab.
RESEARCH INVESTIGATION DIRECTED TOWARD EXTENDING THE USEFUL RANGE OF THE ELECTRO MAGNETIC SPECTRUM Sixth Quarterly Progress Report, Mar. 16-Jun. 15, 1964 R. Novick 15 Jun. 1964 75 p refs (Grants NSG-360; NSG-442; DA-ARO(D)-31-124-G170; DA-ARO(D)-31-124-G380; DA-ARO(D)-31-124-G477 et al (CU-6-64-SC-90789; AD-603446)

Continuous oscillation has been achieved with an optically pumped Rb^{87} maser. This device oscillates at 6835 Mc/sec, corresponding to the hyperfine splitting of the ground state of Rb^{87} . Population inversion is achieved with intensity pumping, and the gain is enhanced by magnetic shielding. The power output is about 10^{-10} W. The hyperfine coupling constants due to quadrupole, spin-rotation, and spin-spin interaction have been determined for NH_2D in the $3_{13}-3_{03}$ rotation inversion transition by means of beam-maser spectroscopy. Also the hyperfine spectrum in the $3_{03}-3_{13}$ rotation-inversion transition of NHD_2 at 18.48191 Gc has been observed, and calculations are in progress to determine the various coupling constants. A detailed electron nuclear double-resonance (ENDOR) study of the self-trapped hole in LiF has been completed. Author

N64-30591 Corning Glass Works, N.Y.
GLASS LASER RESEARCH Semiannual Technical Report, Jan.-Jun. 1964
 M. L. Charters, N. F. Borrelli, P. E. Gordon, and R. D. Maurer
 30 Jun. 1964 47 p refs
 (Contract Nonr-3833(00))
 (AD-443680)

Measurement of relevant physical properties has continued. The technique for measuring absorption loss at 1.06μ has been improved to obtain reliable data from glasses that are not of optical quality. Experimental equipment has been set up to obtain the optical path change with temperature at 1.06μ . The theory of crystal field effects on the fluorescence of Nd^{3+} is examined, and correlation between lifetime and optical absorption pointed out. An analysis is presented of the absorbed energy distribution in a cylindrical laser rod. Author

N64-30685 Technical Operations Research, Burlington, Mass.
THE INVESTIGATION OF PASSIVE LASER Q-SWITCHING Final Report, 1 Apr. 1963-30 Jun. 1964
 J. I. Masters, P. Kafalas, and E. M. E. Murry 30 Jun. 1964
 79 p refs
 (Contract Nonr-4126(00))
 (TO-B 64-54; AD-603115) OTS: \$3.00

The passive Q-switching concept is introduced as an application under the general heading of saturable nonlinear optical elements. The bulk of the laboratory investigation reported is concerned with two organic dye materials for use with ruby lasers—Victoria Blue B deposited on a glass substrate and Cryptocyanine used as a solution contained in a suitable cell. The liquid component operates on a nondestructive radiative process that allows repetitive unattended giant pulse. The liquid, however, may be somewhat slower in switching speed than the Victoria Blue B films that are permanently bleached by thermal dissociation at the onset of each giant pulse. For the particular laser system used in this work, both types of passive switching produced giant pulses of peak power essentially equivalent to pulses that can be obtained by electro-mechanical Q-switching techniques. Author

N64-30907 Columbia U., New York, N.Y. Plasma Lab.
PROGRESS TOWARD A NEON-HYDROGEN LASER AND APPLICATIONS OF OPTICAL PUMPING FOR LASER CROSS-MODULATION Annual Technical Summary Report
 Thomas C. Marshall Jun. 1964 37 p refs
 (Contract Nonr-266(93))
 (AD-603405)

Certain further measurements of the Ne-H₂ mixture are elaborated and refined, and further problems relating to the operation of a Ne-H₂ laser are discussed. Some preliminary results are presented of a series of experiments designed to study, demonstrate, and utilize the effect of high-power optical radiation on an ensemble of metastables that may be contained in an operating laser. The details are reported of a successful attempt to cross-modulate the laser output with an external incoherent optical source and to point out its implications. Author

N64-30992* Ohio State U., Columbus
LASER MATERIALS: A TUTORIAL REVIEW WITH BIBLIOGRAPHY
 James E. Bradley Washington, NASA, Oct. 1964 295 p refs
 (Grant NsG-74-60)
 (NASA-CR-75) OTS: \$4.00

This paper has five tutorial review sections. Crystallography, crystal chemistry, crystal growth, and glass are important topics of discussion in the first four sections. The fifth section deals with the nature of laser ions, and in particular, rare earth and actinide elements. The bibliography is divided into two parts. Part A contains a selected group of reference books, review articles, and bibliographies on subjects related to laser materials. Part B is a partially annotated bibliography of specific references on a group of subjects related to lasers and laser materials. The contents, sources of references, and degree of coverage of each section are given. D.E.W.

N64-31014 Hughes Aircraft Co., El Segundo, Calif. Space Systems Div.
DESIGN OF A LASER DEEP SPACE COMMUNICATION SYSTEM
 Kenneth L. Brinkman and William K. Pratt [1963] 54 p refs

A survey of the state-of-the-art of laser optical detectors, modulation devices, and methods, is given, which establishes the basic properties of the transmitter and receiver system components. Modulation and demodulation systems are analyzed theoretically, and the channel is characterized in terms of the noise contributions from stellar, planetary, and atmospheric background, as well as noise contribution from the components themselves. A systems analysis procedure is developed to select the transmission frequency and the type of receiver. Based on the selection, a choice is made between direct communications from the DSV and communications via a microwave relay satellite. Next, a choice is made of the optimum modulation method for present day systems for the communication link selected. This is followed by a preliminary design analysis of the selected communication system. A comparison of that system with a present day microwave system for interplanetary communications is made. Author

N64-31121 General Electric Co., Syracuse, N.Y. Electronics Lab.
AROMATIC ORGANIC LASER DEVELOPMENT Semi-annual Report, Jul. 1-Dec. 31, 1963
 W. R. Mallory, R. A. Shirk, and D. L. Stockman [1964] 46 p refs
 (Contract Nonr-4135(00); ARPA Order 306-62; Proj. Defender)
 (AD-429409)

The purpose of this program has been to produce coherent stimulated emission in the blue green region in a purely organic dopant and host system. Toward this end, a theoretical analysis of the problem was made, and experimental work on the development of such a laser was done. The theoretical analysis indicates that the short-lived ($\tau \sim 10^{-8}$ seconds) four-level fluorescent compounds are the most suitable materials for this purpose. The principal experimental difficulties have included the development of a suitable host material in which the absorbing and scattering losses are kept to a minimum and an optical pump system capable of efficiently producing several megawatts of absorbable peak power in a short time. Some gain at 4710 Å in a Fabry Perot resonant cavity has been observed, which is probably preoscillation "superradiance." Author

N64-31122 General Electric Co., Syracuse, N.Y. Electronics Lab.
AROMATIC ORGANIC LASER DEVELOPMENT Semi-annual Report, Jan. 1-Jun. 30, 1964
 W. R. Mallory, R. A. Shirk, and D. L. Stockman [1964] 16 p refs
 (Contract Nonr-4135(00); ARPA Order 306-62; Proj. Defender)
 (AD-444962)

*Spectroscopic measurements are reported on perylene and 9-aminoacridine, including absorption and emission curves. A new polymerization catalyst is reported for casting of polymer rods. This catalyst is α,α' -azodiisobutyronitrile. Samples were grown in oxygen evacuated pyrex tubes following a certain temperature cycle for stress optical measurements. Stress-optical coefficient measurements are planned for modified polymethylmethacrylate. A pressurized switch is being tested for use in the optical pump to produce 1-microsecond pulses of 100-Mw peak power. D.E.W.

N64-31142 General Telephone and Electronics Labs., Inc., Bayside, N.Y.

CHELATE LASERS Semiannual Summary Technical Report, 1 Apr.-30 Sep. 1963

A. Lempicki, H. Samelson, and C. Brecher 30 Oct. 1963 22 p refs

(Contract Nonr-4134(00); ARPA Order 306-62; Proj. Defender)

(TR-63-052.2; AD-422363)

Research directed toward obtaining a better understanding of the processes involved in an europium benzoylacetate (EuB) laser is discussed. The research is divided into two main areas: (1) investigation of the processes leading to the generation of laser oscillation—absorption and optical pumping, mechanism of energy transfer, and the fluorescence in the europium ion; and (2) investigation of the nature of the output—divergence, power, mode structure, and monochromaticity. Discussed in detail are the preparation of europium benzoylacetate, spectroscopic properties of EuB, energy transfer, optical pumping, the laser configuration, output beam, and output energy and peak power. P.V.E.

N64-31191 Westinghouse Electric Corp., Baltimore, Md. Air Arm Div.

DEVELOPMENT OF MILLIMETER AND SUBMILLIMETER MASER DEVICES Interim Technical Report, 1 Jun.-30 Sep. 1963

W. E. Hughes [1963] 31 p refs

(Contract AF 33(657)-10472)

(ITR-2; AD-420560)

This report is devoted to operation of a maser using harmonic coupling to establish inversion; studies of new materials— Fe^{3+} in ZnWO_4 and Cr^{3+} in CaWO_4 ; establishing a test facility at Wright Field; relaxation rate measurements for Fe^{3+} in TiO_2 ; and 150 Gc maser pumping configurations.

Author

N64-31247 Naval Ordnance Lab., White Oak, Md.

DETERMINATION OF THE ENERGY OF A PULSED LASER BEAM BY TRANSFER OF THE PHOTON MOMENTUM TO A BALLISTIC TORSIONAL PENDULUM

M. Stimler Oct. 1963 82 p refs

(NOLTR-63-82; AD-420469)

An instrument has been designed and constructed that is capable of measuring high energies of pulsed laser beams, without seriously interfering with their simultaneous use in an experiment. Transfer of the photon momentum of the beam to angular momentum of a doubly reflecting ballistic torsional pendulum was the principle by which photon momentum effects were successfully measured. The instrument operates at 10^{-5} mm of Hg with a sensitivity of 2.55 ± 0.04 cm/joule, and does not require damping of the initial oscillations before making a measurement. It provides the capability of simultaneous energy measurement and use of a laser beam, and

measurements made with this instrument appear to be more accurate than those made with a commercial calorimeter that was used for comparison. Author

N64-31642 International Business Machines Corp., Yorktown Heights, N.Y. Watson Research Center
II-VI LASER MATERIALS STUDY Final Technical Summary Report, 1 Jun. 1963-31 May 1964

G. Mandel, F. F. Morehead, and P. R. Wagner [1964] 121 p refs

(Contract Nonr-4216(00); Proj. Defender)

(AD-442258)

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N64-31811 Centro di Studio per la Fisica delle Microonde, Florence (Italy)

MANY ELEMENT LASERS Scientific Report No. 1

R. Pratesi, L. Ronchi, and G. Toraldo di Francia Apr. 1964 24 p refs

(Contract AF 61(052)-720)

(AFCRL-64-604; AD-603968)

Theoretical and experimental results are reported, obtained with a solid-state laser consisting of many active elements in series. A statistical treatment is developed to derive the oscillation conditions. Asymptotic expressions are given of the threshold gain per unit length holding either for a very large number of elements or for inner surface reflectivities close to 1. Lossless reflections at the inner surfaces can increase the cavity Q with respect to a one-element laser of the same active length. Preliminary experiments with five- and ten-element lasers demonstrate the mode selection property of the many-element laser and show the tendency of the system to a "quasi-continuous" emission. The possibility of obtaining some optical correction of the defects inherent in the solid material has also been demonstrated. Author

N64-31819 General Electric Co., Schenectady, N.Y. Research Lab.

SEMICONDUCTOR DEVICE CONCEPTS Scientific Report No. 8

H. H. Woodbury, M. Aven, P. R. Kennicott, and R. N. Hall Aug. 1964 51 p refs

(Contract AF 19(628)-329)

(AFCRL-64-702; AD-606311)

Studies on the systems CdS:Cu and CdS:Ag have led to the following results: (1) Copper and Ag diffuse very rapidly in CdS, even below 500°C. (2) The segregation coefficient of Ag for CdS, K_d , changes from 5×10^{-7} to 10^{-3} between 500° and 1000°C. (3) the solubility of Ag in CdS depends strongly on the partial pressure of Cd over the crystal. These results are interpreted in terms of interstitial Ag and an undefined complex involving substitutional Ag. The effect of impurities on the electrical characteristics of ZnSe single crystals has been investigated by Hall-effect studies coupled with mass spectrometric measurements. Considerable differences in the impurity spectrum as well as in the electrical behavior of the crystals were found to exist, depending on the starting materials, the crystal growth method, and the purification techniques used. A junction laser structure capable of frequency modulation is discussed. Frequency deviations of the order of 100 Gc at modulation frequencies of several Gc appear reasonable.

Author

N64-31985 National Co., Inc., Malden, Mass.
STUDIES IN EXCHANGE INTERACTIONS TO PRODUCE POPULATION INVERSIONS IN LASER MATERIALS Final Report

George W. Myers, Raoul M. Freyre, William T. Kwo, and Eugene C. La Vier 20 Mar. 1964 49 p refs
 (Contract AF 19(628)-2481)
 (AFCRL-64-261; AD-605730)

The pure chlorides of praseodymium and erbium, and mixtures, were investigated with regard to those properties significant in laser application. Cooperative ion absorptions were examined in PrCl_3 and the cross section was determined for the $^3\text{P}_0 + ^3\text{F}_2$ level. Lifetime of the $^3\text{P}_0$ state in PrCl_3 was determined. The ErCl_3 as well as Er^{3+} in a PrCl_3 lattice was examined for coupled interactions.

Author

N64-32024 Frankford Arsenal, Philadelphia, Pa. Pitman-Dunn Labs.

HUMAN FACTORS STUDY OF DESIGN CONFIGURATIONS FOR THE LASER RANGE FINDER

A. Charles Karr and James T. O'Connor Feb. 1963 64 p
 (R-1664; AD-298098)

An experiment was conducted to compare the accuracies of the proposed design configurations for the laser range finder (shoulder-operated vs bipod-mounted vs high tripod-mounted vs low tripod-mounted). The tripod-mounted configurations provided greatest accuracies. Following the experiment, the observers participated in nonstructured oral critiques of the design configurations, and completed a written questionnaire. The oral and written critiques attempted to elicit from the observers design preferences and design suggestions, considering combat conditions. A majority of the observers preferred the low tripod-mounted configuration and stated that this configuration would be the most practical in combat. A summary of the critiques is presented.

Author

N64-32045 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

GAS AND LIQUID LASERS

Chao-Shou Tseng 13 Aug. 1964 9 p Transl. into ENGLISH from Ko Hsueh Ta Chung (China), no. 11, 1963 p 22 23
 (FTD-TT-64-565/1 + 2 + 3 + 4; AD-605466)

A brief history of the development of lasers is presented along with an outline of the theoretical principles behind ruby, gas, and liquid laser operation.

P.V.E.

N64-32083 North American Aviation, Inc., Canoga Park, Calif. Space and Information Systems Div.

EXPERIMENTAL LASER SPACE COMMUNICATIONS PROGRAM. TASK I: PROBLEM DEFINITION, VOLUME I

9 Oct. 1964 93 p refs

(SID-64-1894-1)

This paper covers the following types of problem definitions for an analytical laser space-communications program: "Types of Optical Effects Associated with Turbulence"; "Summary of Available Measurements"; "Meteorological Optics"; "Theoretical Treatment of Atmospheric Effects"; and "Signal Transfer Analysis."

G.G.

N64-32206 Centro di Studio per la Fisica delle Microonde, Florence (Italy)

LASER CAVITIES TERMINATED BY DIFFRACTION GRATINGS Technical Note No. 1

L. Ronchi and A. M. Scheggi Mar. 1964 33 p refs

(Contract AF 61(052)-536)

(AFCRL-64-355; AD-603967)

A theoretical study is performed of the resonant modes of a laser cavity having end mirrors with periodic reflectivity. A particular example is examined in which the end mirrors are constituted by two identical strip diffraction gratings. The modes and the corresponding eigenvalues are evaluated in successive approximations. It is found that a particular frequency exists for which losses are very low, while neighboring frequencies suffer heavy losses. This effect increases very rapidly with the total number of strips in the grating.

Author

N64-32231 Joint Publications Research Service, Washington, D.C.

TRANSLATIONS ON COMMUNIST CHINA'S SCIENCE AND TECHNOLOGY, NO. 113

6 Oct. 1964 23 p Transl. into ENGLISH from Chinese Periodicals

(JPRS-26744; TT-64-51001) OTS: \$1.00

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1. ABOUT LASERS AND ITS APPLICATIONS Nan-an p 1 8 (See N64-32232 23-25)
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N64-32232 Joint Publications Research Service, Washington, D.C.

ABOUT LASERS AND ITS APPLICATIONS

Nan-an *In its* Transl. on Communist China's Sci. and Technol., No. 113 6 Oct. 1964 p 1 8 Transl. into ENGLISH from Jen-min Jih-pao (Peiping), 7 Sep. 1964 p 5 (See N64-32231 23-25) OTS: \$1.00

For all practical purposes, lasers are an energy conversion unit. The different types of input energy are electromagnetic energy (using radio or light frequencies) or electrical current; the output energy is a stimulated emission of light that has special characteristics—good monochromatic quality (uniform frequency), good directional property (the light bundles are highly parallel), good coherence (the light waves are synchronous), and extreme intensity not shared by other light beams. Four types of lasers already produced are solid state, gaseous, semiconductor, and liquid. The principal applications of

lasers are light communication; light radar and light distance measurement; possibilities for use as antimissile weapons; optical welding, cutting, and hole-punching; and optical surgery. A.W.

N64-32252 Aerospace Corp., El Segundo, Calif. Electronics Research Lab.

POWER DEPENDENT FREQUENCY SHIFTS IN RUBY LASERS AT 77°K

M. Birnbaum and T. L. Stocker 15 Jun. 1964 28 p refs (ATN-64(9216)-3)

Ruby lasers, when operated near threshold at 77°K with a low Q cavity (one end silvered for maximum reflectivity and the other end uncoated) oscillated at two frequencies. The preferred lengths were determined by means of Fabry-Perot etalons. The measured frequency differences near threshold were in good agreement with prior determinations of the splitting of the R₁ doublet by microwave methods. As the power level of the laser was increased, the frequency differences between the oscillating components [2E⁻⁴A₂(±3/2, ±1/2)] were found to decrease. These results are accounted for on the basis of saturation broadening of overlapping Lorentzian lines. The observed variations in the splitting are in good accord with the theory.

Author

N64-32322 Utah U., Salt Lake City Microwave Device and Physical Electronics Lab.

EFFECTS OF GAMMA-IRRADIATION ON THE CHARACTERISTICS OF A RUBY LASER

Vern R. Johnson and Richard W. Grow Sep. 1964 145 p refs (Grants NSF G-15017; NSF GP-843) (NSF-7)

An increase in the absorption cross section responsible for optical pumping of a ruby laser is experienced as a result of γ -irradiation. As single-crystal ruby is irradiated with Co⁶⁰ γ -rays, the usual absorption bands, which exist between 200 and 550 m μ , change from four distinct bands to one continuous absorption band inclusive of all wavelengths between 200 and 550 m μ . Similar work on sapphire, the host crystal for ruby, indicates that the majority of this increased absorption is experienced by the Cr⁺⁺⁺ ion in ruby. Thermoluminescence data are also presented showing that electron traps, metastable states with a high potential barrier, are formed in ruby as a result of γ -irradiation. It is also found that the threshold energy for laser action increases in relation to the amount of γ -irradiation. Using the experimental data of this report as a basis, a model has been devised to explain mathematically what happens to the Cr⁺⁺⁺ ions after γ -irradiation and how this affects laser action.

Author

N64-32383* Massachusetts Inst. of Tech., Cambridge
STIMULATED BRILLOUIN SCATTERING IN LIQUIDS
E. Garmire and C. H. Townes Repr. from Appl. Phys. Letters, v. 5, no. 4, 15 Aug. 1964 3 p refs
(Grant NsG-330; Contract AF 19(628)-4011)

The stimulated Brillouin scattering of a giant-pulse ruby laser beam in liquids generated intense hypersonic acoustic waves without any damage effect, and was used to measure hypersonic velocity in liquids with high accuracy. The lightwaves were generated backward to the laser cavity, amplified, and again entered the liquid, leading to multiple-order stimulated Brillouin scattering by high-order processes within the liquid and without further amplification of the first-order wave. From the measured frequency shift, the hypersonic acoustic velocity of the liquid can be found by an equation. G.G.

N64-32448 Avco-Everett Research Lab., Everett, Mass.
THOMSON SCATTERING COMPUTATIONS FOR LABORATORY PLASMAS

Edward T. Gerry and Richard M. Patrick Aug. 1964 12 p refs (Contract AF 49(638)-1129) (RR-187; AD-603950)

This note presents some calculations of the spectrum of Thomson scattering of a laser beam from typical laboratory plasmas. These calculations are numerical results based on theoretical work by Salpeter. The results show that the character of the spectrum depends upon the ratio of the length in the plasma over which the scattered spectrum adds coherently to the debye length, α . For small α , i.e., $\alpha < 10^{-1}$, the spectrum is simply an electron doppler-broadened spectrum. For medium α ($10^{-1} < \alpha < 1$), the spectrum shows doppler broadening due to both ions and electrons, and for large α ($1 \leq \alpha$) there are peaks in the scattered spectrum displaced from the primary laser frequency by an amount approximately equal to the plasma frequency.

Author

N64-32523 Korad Corp., Santa Monica, Calif.
RESEARCH ON COHERENT ELECTROMAGNETIC RADIATION MATERIALS Final Report

R. C. Pastor and R. H. Hoskins Wright-Patterson AFB, Ohio, ASD, 1 Aug. 1963, 128 p refs (Contract AF 33(657)-8750) (ASD-TDR-63-747; AD-417635)

The objective of this program has been the improvement of laser materials with respect to high output energy and power. Emphasis has been on the growth and evaluation of ruby. Results of detailed studies of the Verneuil (flame fusion) method of crystal growth and, in particular, the technology of the starting powder are presented. Several methods that have been developed for evaluation of rubies, including laser testing, are described. The solutions to several problems relating to crystal quality are given. A substantial improvement in the size and quality of ruby laser crystals was effected. Data obtained on other potential laser materials (Eu⁺³; benzoyl acetate and Mn⁺⁴: α -A₂O₃) are included.

Author

N64-32594 Cutler-Hammer, Inc., Deer Park, N.Y. Airborne Instruments Lab.

TUNABLE MILLIMETER TRAVELING-WAVE MASER AND 8-MM MASER-RADIOMETER SYSTEM Final Report, Part I

F. Arams, B. Peyton, and F. Haneman Apr. 1963 80 p refs (Contract AF 33(600)-41743) (Rept.-8298-1; AD-420126)

A low-noise K_a-band receiving system has been developed that offers a substantial improvement in noise factor (and minimum detectable change in noise temperature) by using a tunable traveling-wave maser and amplifier followed by a transistorized receiver-radiometer system. The K_a-band maser operates over an extremely wide tuning range (5 Gc), and has gains of 20 dB and an instantaneous bandwidth of 75 Mc. A preliminary noise figure measurement has yielded an overall maser-radiometer system noise temperature of 130°K (1.6 dB). The noise temperature of the maser is near 20°K, the remainder being second-stage (mixer, i.f.) contribution and waveguide losses. It follows that optimum system noise temperatures of 38°K are achievable using this maser. The maser uses chromium doped titania (rutile) as the active element. By employing push-pull pumping, a relatively low pump frequency, in the 4-mm band, is obtained.

Author

N64-32607 Massachusetts Inst. of Tech., Cambridge
BASIC PRINCIPLES OF UNCONVENTIONAL GYROS

Derek Howard Baker and James Weatherspoon Harrill 22 May 1964 124 p refs
(Contract AF 33(657)-7668)
(AD-602197) OTS: \$4.00

The basic principles of four representative unconventional gyros are developed. The force between the plates of a charged capacitor manifests itself as the basis for rotor support in the electrostatic gyro. The cryogenic gyro support is dependent on the unusual electric and magnetic behavior of metals at extremely low temperatures. The laser gyro utilizes high-frequency electromagnetic radiation instead of angular momentum to sense inertial rotations. The angular momentum of the nuclear gyro is that of subatomic particles of matter. Author

N64-32756 North American Aviation, Inc., Los Angeles, Calif. Space and Information Systems Div.

EXPERIMENTAL LASER SPACE COMMUNICATIONS PROGRAM. TASK I: PROBLEM DEFINITION, VOLUME II
9 Oct. 1964 320 p refs
(SID-64-1894-2)

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2. THE RELATIONSHIP BETWEEN RANDOM OPTICAL WAVE FRONT DISTORTION AND OPTICAL SYSTEM PERFORMANCE D. L. Fried p 74-134 (See N64-32758 24-08)

3. OPTICAL HETERODYNE DETECTION OF AN ATMOSPHERICALLY DISTORTED SIGNAL WAVE FRONT D. L. Fried p 135-170 refs (See N64-32759 24-08)

4. THE STATISTICS OF GEOMETRICAL INTERPRETATION OF WAVE FRONT DEFORMATION D. L. Fried and J. D. Cloud p 171-184 refs (See N64-32760 24-08)

5. THE SIGNIFICANCE OF THE INNER SCALE OF TURBULENCE TO THE PHASE STRUCTURE FUNCTION J. D. Cloud and D. L. Fried p 185-194 (See N64-32761 24-08)

6. EXTENSION OF RESULTS FOR PHASE AND LOG AMPLITUDE CORRELATION. HIGHER-ORDER TERMS IN THE NEAR-FIELD SERIES AND COVERAGE OF THE FAR-FIELD D. L. Fried and M. F. Sternberg p 195-224 (See N64-32762 24-08)

7. FURTHER EVALUATION OF PHASE AND AMPLITUDE CORRELATION FUNCTIONS FOR AN ATMOSPHERICALLY DISTORTED WAVE FRONT J. D. Cloud p 225-266 refs (See N64-32763 24-08)

8. THE ANGULAR SCINTILLATION CORRELATION FUNCTION D. L. Fried p 267-287 ref (See N64-32764 24-08)

9. RMS ANGULAR RESOLUTION BY THE WAVE FRONT APPROXIMATION TECHNIQUE D. L. Fried p 288-294 refs (See N64-32765 24-08)

10. ATMOSPHERIC OPTICAL DOPPLER: AN APPROXIMATE EVALUATION D. L. Fried p 295-306 refs (See N64-32766 24-08)

N64-32757 North American Aviation, Inc., Los Angeles, Calif. Electro-Optical Lab

ATMOSPHERIC TURBULENCE AND ITS EFFECT ON LASER COMMUNICATION SYSTEMS. SECOND REPORT
D. L. Fried and J. D. Cloud *In its* Exptl. Laser Space Commun. Program Task I: Probl. Definitions, Vol. II 9 Oct. 1964 p 1-73 refs (See N64-32756 24-08)
(TM-91)

A generalization is given of Rytov's method for obtaining an approximate solution of the wave equation for a plane wave propagating through an inhomogeneous medium. This generalization is valid for any wave forms (such as spherical, elliptical, etc.), and from it Rytov's original result for plane waves can be derived as a special case.
D. E. W.

N64-32875 Ohio State U. Research Foundation, Columbus Antenna Lab.

PEAK POWER LIMITER FOR LARGE LASER PULSES
R. G. Tomlinson and E. K. Damon 1 Jul. 1964 13 p
(Contract AF 33(657)-10824)
(Rept.-1579-13; AD-443785)

This report describes a device that limits the peak amplitude of a high-power laser pulse. Control is achieved through an electrodeless discharge produced by the laser pulse in a gas or liquid. For a properly designed system, the peak amplitude of a pulse passing through the power limiter is directly proportional to the pressure of the gas in the limiter provided the pulse entering the limiter exceeds the critical value for that particular system, gas, and gas pressure. The device is passive and lossless, so that it can be used inside or outside the cavity. Some experimental data on the operation of the power limiter using argon as the working substance are presented.
Author

N64-33004 Polytechnic Inst. of Brooklyn, N.Y. Microwave Research Inst.

EFFECTS OF A STATIC MAGNETIC FIELD ON THE CHARACTERISTICS OF A HELIUM-NEON LASER
Paul Fenster Apr. 1964 38 p refs
(Grant AF-AFOSR-453-63)
(PIBMRI-1222-64; AD-601694)

The application of even modest magnetic fields to the amplifying material in the helium-neon laser profoundly modifies the operational characteristics of the laser. The magnetic field introduces a Faraday effect and a Zeeman effect. Both of these effects tend to reduce the power output of the laser. A simple theory is set forth that describes the impact of these effects on the output. The experimental work carried out with a laser oscillating at a wavelength of 6328 Å is generally in agreement with the theory. An attempt is made to explain some observed deviations from the expected results.
Author

N64-33145 Naval Research Lab., Washington, D.C. Optics Div.

LASER RESEARCH Progress Report, 1 Jan.-30 Jun. 1964
J. W. Tucker and J. N. Bradford 31 Jul. 1964 22 p
(NRL-1553; AD-445026)

This report reviews recent laser work. Topics covered include ruby relaxation and fluorescent phenomena, a high-resolution spectrograph that repetitively scans and displays a narrow wavelength interval, a flash lamp operable at 77° K. and evaluation of the optical quality of ruby.
Author

N64-33168* Wheeler Labs., Inc., Great Neck, N.Y.
A MACROSCOPIC WAVEGUIDE MEDIUM FOR LASER SYSTEM COMPONENTS

E. R. Schineller, D. W. Wilmot, and H. M. Heinemann 10 Jun. 1964 81 p refs *Its* Rept.-1209
(Contract NASw-888)
(NASA-CR-58999) OTS: \$3.00 fs; \$0.75 mf

The initial step in the design of microwave-analogous components is the development of a single-mode optical waveguide large enough to permit component fabrication. Single-mode operation is required to prevent signal distortion due

to modal dispersion. A dielectric waveguide for this purpose has been studied, and its feasibility has been demonstrated at optical frequencies. The waveguide dimensions are macroscopic in the sense that they are visible to the naked eye. A single-mode waveguide may be as large as 100 wavelengths with stringent but feasible tolerances on dielectric constant and surface quality. Single-mode and controlled multimode operation have been correlated with theory. In addition, a survey of materials and fabrication techniques has been made.

Author

N64-33275 Sperry Gyroscope Co., Great Neck, N.Y.
ELECTROMAGNETIC ANGULAR ROTATION SENSING
Final Report

W. Macek, R. Salamon, D. Davis, and E. Cheatham Wright-Patterson AFB, Ohio, AF Avionics Lab., Aug. 1964 111 p refs

(Contract AF 33(657)-11433)

(AB-1272-0011; AL-TDR-64-210; AD-605818)

Studies have been conducted on adapting the traveling-wave ring laser for rotation sensing. The three wavelengths of the He-Ne gas system (0.6328μ , 1.1523μ , 3.39μ) have been employed in external cavities with perimeters of 8, 4, and 1 m. The latter two were free to rotate; the 8-m ring was designed to be tilted only, so as to vary the detected component of the earth's rotation. Various optical combiners were evaluated to minimize coupling between the oppositely directed waves while maximizing S/N ratios and permitting the sense of rotation to be determined without recourse to biasing. Coupling effects due to dust particles and mirror surface imperfections were also considered in relation to their effects on mode locking. A region of nonlinear oscillation just prior to frequency pulling and locking, at low rotation rates, has been clearly established and related to the mode coupling problem.

Author

N64-33332* Ohio State U. Research Foundation, Columbus
 Antenna Lab.
PROPERTIES OF MATERIALS FOR SUBMILLIMETER
MASERS

W. S. C. Chang and R. F. Rowntree 5 Feb. 1963 13 p refs /ts Rept.-1093-12

(Grant NsG-74-60)

(NASA-CR-59288) OTS: \$1.00 fs; \$0.50 mf

The particular conditions that are necessary to successfully operate a solid-state submillimeter maser, and the measured properties of the host lattice and of the cavities are discussed. It is concluded that the selected active material must have a resonance absorption Q equal to 10^3 or better (i.e., the resonant absorption coefficient, K_{st} , must be approximately 1 cm^{-1}) with a population inversion ratio of 10% or better. Also, any material in which an electric dipole transition does not occur will probably not make a good submillimeter maser material. From existing submillimeter spectroscopic data in solids, it appears that K_{st} of this order of magnitude should be available in many materials, and that the major obstacle would be the achievement of a reasonable population inversion ratio.

D.S.G.

N64-33346 Joint Publications Research Service, Washington, D.C.
EXCERPTS FROM "LASERS IN SPACE, ON THE GROUND,
AND UNDER WATER"

V. N. Chernyshev 30 Oct. 1964 16 p Transl. into ENGLISH of excerpts from the booklet "Lazery v Kosmose. Na Zemle, i Pod Vodoy" Moscow, Voenizdat, 1964, p 90-101

(JPRS-27167; TT-64-51423) OTS: \$1.00

The development in the United States of lasers as potential weapons to be used against ballistic missiles or against personnel is discussed. The scientific and industrial applications to which lasers may lend themselves are explored. Some of the applications are in communications, high-speed memories, welding and cutting, fusion or evaporation, power transmission, high-resolution photography, frequency standards, chemical reaction control, and surgical operations. Current trends of thought in the press are noted, and the widespread interest in lasers is indicated.

D.E.W.

N64-33692 Rochester U., N.Y. Inst. of Optics
INVESTIGATIONS OF OPTICAL MASERS Final Report
 Robert E. Hopkins Sep. 1964 11 p refs
 (Grant DA-ARO(D)-34-124-G324)
 (AROD-3309-5; AD-450074)

Research accomplishments in a basic study of ruby-laser emission and in optimum design and construction of visible helium-neon gas lasers are outlined. The initiation of the following studies is also reported: (1) laser radiation-damage studies; (2) design and analysis of Q-switching techniques; (3) optical characteristics of second harmonic radiation generated within nonlinear media; and (4) optimum coupling between the output from a gas laser and various nonlinear media. Accumulated laser-research equipment is being used to introduce lasers in the optics curriculum.

M.P.G.

N64-33749 Radio Corp. of America, Princeton, N.J. RCA
 Labs.

SYSTEMATIC STUDY OF THE CRYSTAL FIELD OF CaF_2
Final Report, Apr. 1, 1963-Mar. 31, 1964

Herbert A. Weakliem 20 Aug. 1964 42 p refs

(Contract Nonr-4133(00); ARPA Order 306-62; Proj. Defender)
 (AD-446246)

Crystals of CaF_2 containing transition metal ions and crystals of CdF_2 containing transition metal and rare-earth ions have been grown, and the spectra were measured. The transition metal ions either are not fluorescent or have only broad fluorescent bands. The ions in the first half of the 3d series prefer the 3+ oxidation state and were found to have large Dq values (1000 to 1500 cm^{-1}), whereas those in the latter half of the series prefer the 2+ oxidation state and have Dq values less than 500 cm^{-1} . The rare-earth ions all go into CdF_2 in the 3+ oxidation state and apparently cannot be reduced to the 2+ state. The absorption and fluorescent spectra of the CdF_2 rare-earth-doped crystals are typical of those seen for rare-earth ions in many other crystals. The linewidths of the narrow fluorescent lines in $\text{CaF}_2:\text{Tm}^{2+}$ and $\text{CaF}_2:\text{Dy}^{2+}$ were studied by conventional spectrographic, interferometric, and optical magnetic resonance methods.

Author

N64-33805* General Dynamics/Electronics, Rochester, N.Y.
 Research Dept.

LASER MODULATION AT THE ATOMIC LEVEL Monthly
Report No. 2, 1-31 August 1964

E. G. Brock, F. C. Unterleitner, Y. C. Kiang, and J. F. Stephany
 10 Sep. 1964 13 p refs

(Contract NASw-1008)

(NASA-CR-59313) OTS: \$1.00 fs; \$0.50 mf

The determination of gain in ruby as a function of magnetic field was continued, with some indication of the appreciable influence of excited state absorption upon the measurements. Substitution of $\text{YAG}:\text{Nd}^{3+}$ for $\text{CaF}_2:\text{Dy}^{2+}$ as the initial laser material to be studied is suggested. Preparations for the experimental observation of the Zeeman splitting of the laser emission in a homogeneous pulsed field are described. Author

N64-33806* General Dynamics/Electronics, Rochester, N.Y. Research Dept
LASER MODULATION AT THE ATOMIC LEVEL Monthly Report No. 3, 1 Sep.-30 Sep. 1964

E. G. Brock, F. C. Unterleitner, Y. C. Kiang, and J. F. Stephany
 10 Oct. 1964 12 p ref
 (Contract NASw-1008)
 (NASA-CR-59314) OTS: \$1.00 fs, \$0.50 mf

The absorption of a ruby rod is described in the presence of absorption by the metastable state in the wavelength region of interest and with some inhomogeneity in pumping along the length of the rod. The results of transmission measurements at room temperature and at 115° K are presented and interpreted by means of the theory. Initial testing of a YAG Nd³⁺ laser rod is described. Author

N64-33839 Grumman Aircraft Engineering Corp., Bethpage, N.Y. Research Dept

CONTROL OF LASER RADIATION WITH BIREFRINGENT CRYSTALS: THE MICROWAVE CIRCUIT VIEWPOINT
 M. R. Wohlers and K. G. Leib Jun. 1964 11 p ref
 (RM-2345)

Microwave circuit theory is utilized to describe three devices that control coherent optical beams using birefringent crystals. A frequency demodulator uses the difference of the index of refraction along two axes of a birefringent crystal together with a Fabry-Perot interferometer to obtain an s-type frequency discriminator. An optical isolator consists of a crystal and a polarizer functioning in such a way that the input of the device is isolated from the reflection that can occur at its output. An optical switch is based on the filter characteristics of a Fabry Perot interferometer, which can be adjusted using an electrically activated birefringent crystal. Author

N64-33925 American Optical Co., Southbridge, Mass. Research Center

NEODYMIUM LASER GLASS IMPROVEMENT PROGRAM
Technical Summary Report, 30 Jun. 1963-30 Jun. 1964
 Richard F. Woodcock Sep. 1964 24 p refs
 (Contract Nonr-3835(00), ARPA Order 306-64, Proj. Defender)
 (TSR-4; AD-605517)

Investigations were carried out in the areas of laser glass compositions that are nonsolarizing, of the effect of host glass composition on fluorescent lifetime, of analysis of the fluorescent decay curve, and of laser threshold studies D E W.

N64-33944 Technical Research Group, Inc., Melville, N.Y.
RESEARCH ON PROPERTIES OF LASER DEVICES Ninth Quarterly Technical Summary Report, 1 Jun.-31 Aug. 1964

R. Kaplan, ed. [1964] 49 p refs
 (Contract AF 49(638)-673; ARPA Order 256-62; Proj. Defender)
 (TRG-134 QTR 9; AD-447907)

Apparatus has been completed for testing the principle of relaxation of the lower laser level in a gas discharge by inelastic atom-atom collisions. An alumina tube for containing a manganese noble gas mixture at 1350° C has been rebuilt. He-Xe test oscillations have been generated in this tube at 1350° C. A resistance-heated tantalum tube for containing a lanthanum noble gas mixture at 1800° C has been completed. A discharge current density of 0.5 A/cm² has been achieved between this tube and a concentric tungsten filament over a length of 10 cm. Further progress has been made in the investigation of improvements in energy radiance that can be achieved by mode selection in a ruby cavity. An accurate technique for measuring pulse energy per unit solid angle has been established. Author

1965

STAR ENTRIES

N65-10043*# Ohio State U. Research Foundation, Columbus Antenna Lab.

INVESTIGATIONS OF MASERS UTILIZING CROSS-RELAXATION

M. H. Spring 15 Oct. 1963 77 p refs /Its Rept.-1093-23 (Grant NsG-74-60)

(NASA-CR-59406) OTS Prices: HC \$3.00/MF \$0.75

The study of cross-relaxation effects in paramagnetic crystals is of great intrinsic interest to millimeter-wave maser technology because of the possibility of obtaining maser amplification at higher frequency than that of the pump source. The quantum mechanical calculation of cross-relaxation rates, the rate equation analysis of the maser, and the experimental measurement of cross-relaxation rates are presented. It was shown that in materials such as ruby or emerald, the cross-relaxation rate is not sufficiently strong to be practical to build a maser with its signal frequency much larger than its pump frequency. However, cross-relaxation processes can hinder or assist maser amplification in a given maser amplifier. Author

N65-10248# Utah U., Salt Lake City
MICROWAVE DEVICE AND PHYSICAL ELECTRONICS
LABORATORY CONSOLIDATED QUARTERLY REPORT,
APRIL 1-JUNE 30, 1964

30 Jun. 1964 117 p refs
 (Contracts Nonr-1288(05), AF 04(693)-439; AF 33(657)-8677; DA-36-039-AMC-0237Z-(E))
 (MDL-Q9; AD-605418)

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N65-10294# Aerospace Corp., El Segundo, Calif. Space Physics Lab.

STAR-FIELD PHOTOGRAPHY AND LASER RANGING TECHNIQUES FOR SATELLITE-BASED GEODETIC MEASUREMENTS

E. B. Mayfield and E. H. Rogers 15 Sep. 1964 35 p ref (Contract AF 04(695)-269)
(SSD-TDR-64-145; TDR-269(4710-63)-1; AD-607137)

A method is described for obtaining cartographic and geodetic data from a manned orbital satellite. The techniques utilized are a boresight camera, which simultaneously photographs a particular point on the ground and the coaxial star field, and a laser for obtaining slant range. These, together with an accurate spacecraft ephemeris, will obtain data on angle coordinates and elevation of particular points along the orbital trace of the spacecraft with respect to a primary control station. Particular instrumental requirements are given for the star-field camera and the laser ranging device. Author

N65-10386# Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.

A MILLION SUNS IN CRYSTAL

N. Yil'yn 1 Oct. 1964 8 p Transl. into ENGLISH from Sov. Patriot (USSR), 20 Mar. 1963 p 3
(FTD-TT-64-794/1; AD-607313)

This paper describes the mechanism of a ruby laser. The laser's possible application as a weapon in warfare—to destroy instantaneously the enemy's living forces, as well as his war potential of guided missiles, aerospace targets, tanks, surface vessels, and defense installations—is discussed. The utilization of the laser beam for a television system and in other communications media is also presented. G.G.

N65-10405# Ohio State U. Research Foundation, Columbus Antenna Lab.

STUDY OF MICRON WAVE PROPAGATION Annual Summary Report, 1 Jan.-31 Dec. 1963

1 Jan. 1964 59 p refs
(Contract AF 33(657)-10824)
(Rept.-1579-9; AD-447881)

Factors limiting the transfer of laser radiation from source to receiver are discussed. The mutual coherence function is modified to describe the collimation and focusing capability of a partially coherent source, and calculations of the diffraction patterns of partially coherent circular apertures are made. A suitable criterion for laser-induced atmospheric breakdown is introduced, and nonlinear propagation factors are discussed. The theory of parametric interactions of radiation and matter is generalized. Resonant atmospheric absorption data are summarized for the majority of laser wavelengths. Related activity in laboratory source and instrumentation development is reviewed. Author

N65-10427# Varian Associates, Beverly, Mass. Bomac Div.
HYDROGEN MASER PROGRAM Interim Technical Report, 1 Sep. 1961-1 Jul. 1963

R. Vessot 20 Aug. 1963 83 p refs
(Contract Nonr-357(00))
(AD-422859)

The properties of frequency stability of the hydrogen maser and its application as a time standard, as well as the interaction of the atomic hydrogen with the surface atoms that line the confining bulb, and the interaction of the hydrogen atoms with the Lyman alpha radiation are studied. The following topics are presented: "Hydrogen Handling and Atomic Hydrogen Sources"; "Hydrogen Pumping"; "The Hexapole Magnet Star Selector"; "The Storage Bulb and R.F. Structure"; "Thermal and Magnetic Field Control and Magnetic Shielding"; "The Vacuum Envelope"; "Measurements and Data"; and "Work in Progress." G.G.

N65-10492# Army Signal Research and Development Agency and Lab., Fort Monmouth, N.J. Solid State and Frequency Control Div.

DESIGN THEORY FOR LASER AMPLIFIERS

H. Jacobs, F. A. Brand, S. Weitz, and C. Lo Cascio Jul. 1964 46 p refs
(TR-2486; AD-607057)

It was predicted in earlier work that for a given length of crystal where there are multiple reflections, the transmitted gain would rise with negative attenuation, reach a maximum and then reverse its direction, decreasing rapidly at first, and then gradually approaching an asymptotic value of zero. In the present writing experiments have been initiated to investigate the validity of the theory using ruby at liquid nitrogen temperatures. A transmission system was set up with an oscillator, a filter, an amplifier, and a detector. By controlling the relative time delays in firing or by changing the power input to the amplifier, the properties of transmitted power gain were studied. It was found that both the oscillator and amplifier rubies in uncoated form could be made to oscillate for about 100 μ sec giving a well-defined pulse of quasi-cw operation. The gain of the amplifier increased as the times of the signal from the oscillator approached the time at which the amplifier went into oscillation. Author

N65-10518# New Mexico State U., University Park Research Center

VARIATION OF REFRACTIVE INDEX DURING LASER OPERATION Semiannual Technical Report

J. R. Izatt, H. A. Daw, and R. C. Mitchell Jul. 1964 30 p refs
(Contract Nonr-3531(04))
(SATR-2; AD-603450)

Experimental determination of the effect of optical pumping on the refractive index of ruby in the region of anomalous dispersion surrounding the R_1 line requires a ruby sample of high optical quality. Shadowgraph and small-angle scattering measurements combined with some interferometric measurements in which the ruby serves as the spacer in a Fabry-Perot etalon indicate that a small Linde ruby has sufficient optical quality to allow accurate measurements of the minute index changes that are anticipated, i.e., changes smaller than 1 part in 10^4 . The experimental approach used was to measure the refractive index changes requires photographing a set of Fabry-Perot fringes, whose relative positions are determined by the index changes, against a background set of fringes that serve as fiduciary marks. The feasibility of extracting quantitative information from the composite fringe patterns depends on the detailed spectral structure of the light that produces the fringes and also on rather critical control of relative exposure. Author

N65-10722 # Varian Associates, Beverly, Mass.
FREQUENCY BEAT EXPERIMENTS WITH HYDROGEN MASERS

R. F. C. Vessot and H. E. Peters *In* Army Signal Res. and Develop. Agency and Lab. Proc. of the 17th Ann. Symp. on Freq. Control [1963] p 372-391 refs (See N65-10701 01-07) (Contracts NAS8-2604; Nonr-3570(00))

Data describing the results of comparison measurements made by beating two atomic hydrogen masers are presented. These measurements have indicated that the rms fractional frequency deviations attributable to one maser for various measuring intervals are as follows:

$$\begin{aligned} &1.5 \text{ sec. } 5.6 \times 10^{-12}; \\ &10 \text{ sec. } 1.07 \times 10^{-13}; \text{ and} \\ &1 \text{ hr. } 2.4 \times 10^{-13}. \end{aligned}$$

The 1.5-sec and 10-sec measurements are limited by receiver noise, and the 1-hr measurements, by systematic effects due to drifts in the ambient temperature. A description of the apparatus and its control systems are given; and the effect of receiver noise on the calculated stability are discussed. A new smaller version of this device is described, and the possibilities of using the device in a satellite are explored. Author

N65-10725 # Technical Research Group, Inc., Syosset, N.Y.
FREQUENCY STANDARDS IN THE OPTICAL RANGE

Gordon Gould *In* Army Signal Res. and Develop. Agency and Lab. Proc. of the 17th Ann. Symp. on Freq. Control [1963] p 425-437 refs (See N65-10701 01-07)

Methods for centering a cw gas-laser oscillation frequency on the fluorescent line have been studied theoretically and experimentally. A piezoelectric crystal has been used to control the cavity length and the oscillation frequency. With a heterodyne detector and feedback circuit one such single-mode He-Ne laser has been frequency locked to another within 3000 cps or better than 1 part in 10^{11} . Several ways of sensing the deviation of the laser frequency from line center have been considered. A very sensitive null indicator is a power-dependent frequency shift that is a linear function of frequency displacement from line center. By power modulating one laser and using a second laser as local oscillator it should be possible to center both within 1 part in 10^{10} . Analysis and experimental results are presented. Author

N65-10728 # Naval Observatory, Washington, D.C.
REPORT ON THE FREQUENCY OF HYDROGEN

William Markowitz *In* Army Signal Res. and Develop. Agency and Lab. Proc. of the 17th Ann. Symp. on Freq. Control [1963] p 462-463 (See N65-10701 01-07)

The frequency, ν_H , of a hydrogen maser of the Ramsey type was determined, to the second, of Ephemeris Time during a 2-week interval in May 1963. Values were determined for 10 intervals, averaging 1 day each, with mean epochs from May 12.3 to 23.4, 1963. The probable error of a single determination is ± 0.005 cps, with respect to the frequency system of the Naval Observatory. Three mean values are given, the number of significant figures reflecting the accuracies involved in the reference system. D.S.G.

N65-10907 # Aeronutronic, Newport Beach, Calif.
LASER PUMPING SOURCES Final Technical Report
 S. Byron, H. Shanfield, W. Lawrence, J. Killian, and D. Peters
 15 Jul. 1964 72 p refs
 (Contract Nonr-4237(00); ARPA Order 306-62; Proj. Defender)
 (U-2771; AD-605414)

Successful efforts to overcome the limiting factors associated with adapting explosive light sources to laser pumping are reported. Two modifications were made to the argon flash bomb and involved the following: (1) the use of stationary reflected shock-heated gas as the radiation source; and (2) the use of subatmospheric xenon as the gas to be shock heated. In principle, these changes allow an order of magnitude increase in radiation pulse duration and two orders of magnitude decrease in mass of explosive used; in practice, a radiation pulse was produced over a stationary area of 5 cm^2 , having a peak brightness temperature at 5600 \AA of $12,300^\circ \text{K}$, and remaining above 6000°K for $450 \mu \text{sec}$, through the use of only 1 g of stored chemical energy. This radiation source was used to stimulate laser action in a neodymium-doped glass rod with no damage to the laser crystal. Other studies of pyrotechnics and explosive-pyrotechnic combinations to produce elevated radiation temperatures indicate that there is a fundamental upper limit of about 5000°K in the visible spectrum range in the radiation intensity that can be achieved directly from high-energy density, chemically reacting systems. M.P.G.

N65-11333 # Air Force Inst. of Tech., Wright-Patterson AFB, Ohio

INVESTIGATION OF A LASER TRIGGERED SPARK GAP
 Winston K. Pendleton (M.S. Thesis) Aug. 1964 58 p refs
 (GNE/PHYS/64-13; AD-603613)

A focused, Q-spoiled laser beam was used to produce an arc in a sphere-sphere electrical gap charged to within 30% to 90% of self-breakdown. The time response of the triggering was measured as a function of: laser beam power, 0 to 80 MW; fill gas, SF_6 , N_2 , Air; gas pressure, 100 to 1400 mm of Hg; electrode spacing, 0.4 to 1.5 cm; gap electric field, 10 to 100 kV/cm; and focus point location. Short delay times as low as 20 nsec were measured in SF_6 at atmospheric pressure. Generally delay times varied inversely with the electric field, gas pressure, and focus point distance from the anode surface. The results obtained were considered consistent with those predicted by the streamer theory of arc formation. Author

N65-11387 # Lincoln Lab., Mass. Inst. of Tech., Lexington
SOLID STATE RESEARCH
 1 Sep. 1964 94 p refs
 (Contract AF 19(628)-500)
 (ESD-TDR-64-351; AD-606126)

The following topics are presented: "Solid State Device Research"—diodes of PbTe, the interface-alloy junctions between InAs and GaSb, the vapor growth of $(\text{Ga}_x\text{In}_{1-x})\text{As}$ single crystals, and n-GaAs at high electric fields; "Laser Research"—the Raman laser program, the optical maser properties of CeF_3 , the laser-created gaseous breakdown of air and argon, a pulsed-laser dosimeter, and a gas-laser program; "Materials Research"—the optical measurement of an rf generator output, the analysis of crystal growth from vapor, the electrical properties of transition metal oxides, the transformation heat of Ag_2Se , the rate of cubic-to-hexagonal transformation in $\text{PrO}_{1.5}$ and the rate of transformation in $\text{InSb}_{1-x}\text{Sn}_x$ alloys, the pressure dependence of resistance of $\text{Cd}_x\text{Hg}_{1-x}\text{Te}$, the partial pressures for CdTe(c), and wet chemical analysis of MnO and CoO; "Band Structure and Spectroscopy of Solids"—investigated are HgTe, antimony, germanium, Mg_2Ge , and the symmetry theory of the Seebeck coefficient; and "Magnetism and Resonance"—theory and experiment. G.G.

N65-11670 # Eastman Kodak Co., Rochester, N.Y. Apparatus and Optical Div.
LASER MATERIAL STUDY Semiannual Technical Report,
 1 Jan.-30 Jun. 1964

P. B. Mauer [1964] 11 p refs
(Contract Nonr-3834(00); Proj. Defender)
(AD-604443)

A performance study was made of two types of laser material, matched quite closely in all characteristics except their fluorescence lifetime. Data were recorded to indicate conversion efficiency as a function of input power and the reflectivity of the output mirror. In addition, an estimate of beam divergence was made by comparing images recorded on carbon paper or on developed, unexposed, Polaroid print paper. Conclusions were drawn from these data as to the role of fluorescence lifetime and its related quantum efficiency to the practical performance of a laser material. Author

N65-11687# Aerospace Corp., El Segundo, Calif. Electronics Research Lab.

ELECTRONICS RESEARCH PROGRAM: RESEARCH AND EXPERIMENTATION IN OPTICAL PHYSICS Semi-annual Technical Report, 1 Jul.-31 Dec. 1962

P. Kisliuk 1 Apr. 1963 24 p refs
(Contract AF 04(695)-169)

(TDR-169(3250-24)TN-1; SSD-TDR-63-59; AD-403372)

Temperature dependence of the absorption strength of the N_1 and N_2 lines of concentrated ruby, attributed to exchange coupled pairs of Cr^{+3} ions, was studied. On this basis, tentative assignments were made for sign and magnitude of exchange coupling (assumed to be isotropic) and for total spin in the lower state of transition. Other observed lines can then be assigned to transitions between the same upper level and lower levels of different total spin; this agrees with the interval rule and is consistent with the temperature dependence of the lines. Erbium-doped lanthanum trifluoride is discussed briefly. Experiments on mechanical Q-switching and on thermoluminescent crystals are noted briefly. Author

N65-11773# California U., Berkeley Electronics Research Lab.

LASER BEAM EXCITATION OF LASERS Final Report

J. R. Singer 31 Aug. 1964 7 p refs /ts Rept.-64-33

(Contract DA-ARO-D-31-124-G-317)

(AROD-3323-5; AD-607783)

The optical maser (laser) excitation of another optical maser has been shown to be theoretically practical. The method of excitation consists of providing a pulse of laser radiation at the appropriate wavelength and for the appropriate length of time to cause a 180° inversion in the population levels of a laser material. Reasons for the importance of the 180° inversion laser-excitation method are these: (1) There is essentially no heat loss in the excitation process and cooling is not necessary. (2) The inversion is practically complete, and more laser output from the excited laser is available than with other excitation methods for solid laser materials. (3) The excitation process is, essentially, more efficient. P.V.E.

N65-11823# Sperry Gyroscope Co., Great Neck, N.Y. Electro-Optics Group

LASER MODE INTERACTION STUDIES Final Report

S. A. Collins, Jr., C. C. Wang, and E. W. Cheatham Aug. 1964 34 p refs

(Contract AF 19(628)-2924)

(AB-1272-0021; AFCRL-64-701; AD-608175)

The optical resonator theory was experimentally applied to a triangular ring optical resonator. Beat frequencies between various modes were measured. The results were in agreement with the analytically predicted frequencies. A GaAs diode

laser with an external ellipsoidal mirror was analyzed and experimentally studied. Reduction of spot size is treated, and the apparatus to position the diode-mirror combination is described. Dual, canted, Fabry-Perot mode-selector etalons were experimentally studied with a ruby laser. Beam-angle narrowing in two dimensions is shown. The theory of frequency selectivity and angle narrowing is reviewed. Author

N65-11878# Spectrolab, Inc., Sylmar, Calif.

DESIGN AND FABRICATION OF OPTICAL FILTERS FOR LASER FREQUENCY Technical Documentary Report, Feb. 1963-Jul. 1964

Samuel J. Holmes and Noel E. Bowman Wright-Patterson AFB, Ohio, AF Avionics Lab., Oct. 1964 71 p refs

(Contract AF 33(657)-9216)

(AFAL-TR-64-268; AD-608064)

Theoretical aspects, production methods, and evaluation techniques of narrowband optical filters, which employ a thin sheet of mica in place of the usual evaporated dielectric spacer layer, are described. Such filters have been made and are reported with half-widths of less than 2 \AA and with transmission on the order of 60%. In particular, details are given of the method of cleaving the mica sheets and the measurement of absorption. A filter holder is described that makes it possible to construct filters of practical size. Theoretical and experimental values are given for the angular sensitivity. Other properties discussed are the tunability, background, the spectral region for which they can be constructed, and the stability of the filters with time and with temperature changes. Author

N65-11886# Sperry Gyroscope Co., Great Neck, N.Y. Electro-Optics Group

COHERENT OPTICAL ARRAY TECHNIQUES Interim Technical Documentary Report, 1 Mar.-31 May, 1964

Griffiss AFB, N.Y., RADC, Sep. 1964 71 p refs

(Contract AF 30(602)-3329)

(AB-1272-0016-1; RADC-TDR-64-315; AD-608220)

The overall plan is to demonstrate feasibility by developing a subassembly consisting of a cw-laser master oscillator driving two pulsed-laser power amplifiers in parallel. The required phase shifters and power dividers would be incorporated to demonstrate the principles of a coherent optical phased array. The investigation is being conducted for an operating wavelength of 1.06 microns. Solid-state and gas lasers are being considered for the master oscillator. Each type has been developed for fully cw operation in the vicinity of 1.06 microns. Solid-state crystals have been grown, cut, polished, and coated for amplifier functions of the same wavelength. Gain of several decibels has been measured. Author

N65-12060# ITT Industrial Labs., Fort Wayne, Ind.

IMPROVED QUANTUM EFFICIENCY LASER DETECTORS Interim Engineering Report

E. H. Eberhardt and J. L. Gumnick 9 Oct. 1964 56 p refs

(Contract AF 33(615)-1596)

(AD-606680)

The optical properties of thin films and arrays of thin films to be used as photocathodes, as well as their overall photoexcitation and emission phenomena, are being investigated. Also, the development of an electron multiplier that is to be associated with a laser detector is discussed. Work on photocathodes includes theoretical analysis, experimental results and procedures, stock tubes, special tubes, and vidiscor tubes. A discussion of electron multiplier improvement includes reducing the number of stages of electron multipliers

and improving anode geometry, resistive end plates, first dynode, and front end geometry, and advanced anode geometry.
P.V.E.

N65-12155# Radio Corp. of America, Camden, N.J. Applied Research Dept.

FEASIBILITY OF TECHNIQUES FOR A DOPPLER OPTICAL NAVIGATOR Final Report, Jun. 1963-Jun. 1964

W. J. Hannan, L. J. Nicastro, T. E. Penn, and J. Vollmer Wright-Patterson AF8, Ohio, AF Avionics Lab., Sep. 1964 142 p refs

(Contract AF 33(657)-11458)

(AL-TDR-64-209; AD-605819)

The objective was to determine the feasibility of novel laser techniques for doppler optical navigation. The ultimate performance goal is the measurement of ground speed of a satellite, traveling at a velocity of 10 000 meters per second at an altitude of 300 miles, with an accuracy of 5 meters per second. Either of two approaches can be used to instrument a doppler optical navigator—the continuous-wave approach, or the subcarrier approach. Under cw operation the receiver utilizes coherent detection techniques that suppress the effects of background noise and dark current in the photodetector. However, a cw system requires a complicated receiver, for not only must a coherent optical detector be used, but the receiver must be capable of tracking doppler shifts that could be as high as 20 Gc. On the other hand, the subcarrier approach allows the use of a relatively simple receiver, since noncoherent detection techniques can be used and since doppler shift of the subcarrier is much smaller; but it suffers from the disadvantage that neither background radiation nor dark current of the photodetector can be suppressed easily. The results of the investigation of the subcarrier approach reveal that it offers a potential advantage over a microwave system for high-altitude applications, but at the present state-of-the-art the laser transmitter power required at these altitudes cannot be realized. Author

N65-12279# Sylvania Electric Products, Inc., Mountain View, Calif. Optics Dept.

LIGHT MODULATION DETECTOR Interim Engineering Report No. 1, 15 Apr.-15 Jul. 1964

Russell Targ, D. E. Caddes, E. O. Ammann, G. A. Massey, S. E. Harris et al 20 Jul. 1964 66 p refs

(Contract AF 33(615)-1938)

(FDL-M739; AD-604022)

The work was divided into three main phases: (1) the development of a single-sideband suppressed-carrier-laser local oscillator with maximum power; (2) control of the modes of a laser by interferometric means to assure monochromatic output; and (3) design of an automatic frequency control system to tune the laser LO in frequency in accordance with the changes in the carrier frequency of an incoming signal from an independent laser transmitter. Work is also reported on techniques that allow certain electro-optic devices such as light modulators and shutters to be used with arbitrarily polarized light. Author

N65-12282# Conductron Corp., Ann Arbor, Mich.

COHERENT LIGHT INVESTIGATION, VOLUME I

G. Cochran et al Wright-Patterson AFB, Ohio, ASD, Mar. 1964 181 p refs

(Contract AF 33(615)-1014)

(D-5210-70-T80-110; AD-606323) OTS: \$5.00

Although both the coherent and incoherent nature of light can be completely treated by wave mechanics methods, a simplified approach can be used. The latter is divided into the use of quantum theory when light is radiated or adsorbed by a material such as an atom and the use of the classical Maxwell theory to explain transfer functions, diffraction effects, and interference of light. Transfer-function mathematics are developed whereby the electromagnetic field of three-dimensional space at one position may be described as a function of the three-dimensional electromagnetic field at another position in space. Propagation of energy at optical wavelengths can be treated when such energy is transmitted through gas or solid materials in which statistically or mathematically describable perturbations of phase take place. A comparison of optical and microwave radars and a discussion of the use of a laser in optical measurements are included. M.P.G.

N65-12477# Ohio State U. Research Foundation, Columbus, Antenna Lab.

EXPERIMENTAL DATA ON THE BREAKDOWN OF AIR AND ARGON BY A RUBY LASER PULSE

R. G. Tomlinson and E. K. Damon 1 Jun. 1964 23 p

(Contract AF 33(657)-10824)

(Rept.-1579-12; AD-443784)

Data on laser-induced gas breakdown in air and argon were taken as functions of gas pressure and peak laser-pulse power. As the gas pressure is lowered for a fixed laser-pulse power, or as the peak laser power is lowered for a fixed gas pressure, breakdown occurs at a later and later time relative to the beginning of the laser pulse, until a threshold is reached below which breakdown does not occur. These data are primarily measurements of percent laser-pulse energy transmitted through the breakdown region. Direct photographs of the focused laser spot were made and used to convert power measurements to electric field strength values. Author

N65-12774# Stanford U., Calif. Microwave Lab.

NONLINEAR INTERACTIONS BETWEEN RADIATION AND SYSTEMS WITH QUANTIZED ENERGY LEVELS Final Report, 15 Mar. 1962-15 Mar. 1964

R. H. Pantell Jul. 1964 69 p refs

(NSF G-22929)

(ML-1194)

Experiments were performed using the photoconductive effect in bulk semiconductors to produce a microwave beat frequency from two axial-mode laser frequencies. A specialized photoconductive frequency mixer, analyzed in terms of its parametric conductances, was developed. Noise calculations indicated that this bulk semiconductor is theoretically quite competitive with the PIN photodiode. G.G.

N65-12920# Brown Engineering Co., Inc., Huntsville, Ala. Research Labs.

OBSERVATION OF STATISTICAL FLUCTUATIONS IN OPTICAL SECOND HARMONIC GENERATION

J. William Foreman, Jr. Nov. 1964 22 p refs

(TN-R-121; AD-608670)

Measurements of the statistical fluctuations in optical second-harmonic generation have been made using both short- and long-time constant detector circuits. The second harmonic was generated by focusing the beam from a standard ruby laser (not Q-switched) on a KDP crystal mounted approximately in the phase-matched orientation. As expected, the measured

fluctuations were smaller in the long-time constant case. A steady decrease in second-harmonic output was observed throughout the measurements. Some possible reasons for this anomalous effect are discussed. Author

N65-12961# Harvard U., Cambridge, Mass. Cruft Lab.

A 21-CENTIMETER TRAVELING-WAVE MASER

E. B. Treacy 22 Jan. 1963 40 p refs

(Contract Nonr-1866(28))

(TR-401; AD-405055)

A traveling-wave maser, tunable over the frequency range of 1340 to 1430 Mc, was developed and constructed for use in radio astronomical research. It uses ruby as the maser material and a comb as the slow-wave structure. The net gain exceeds 30 dB over most of its tuning range, and the average instantaneous bandwidth is about 11 Mc. It has been designed for operation at 4.2° K. Author

N65-13041# Army Signal Research and Development Agency and Lab., Fort Monmouth, N.J. Electronic Components Dept.
BEAM DIVERGENCE AND FAR-FIELD PATTERNS OF RUBIES OF VARYING OPTICAL QUALITY

C. M. Kellington and M. Katzman Jul. 1964 23 p refs

(ECOM-2478; AD-608717)

Beam divergence at 10 dB from extinction was measured, and far-field patterns were photographed for 37 ruby rods of different quality. The growth with pumping power of the most intense portion of the laser beam was measured for two rods of very different quality. An autocollimator reticle image was photographed after passage through each rod. Correlation of beam divergence with optical parameters is discussed. Author

N65-13138* # Kollsman Instrument Corp., Elmhurst, N.Y.

STUDY OF LASER POINTING PROBLEMS Bi-Monthly
Technical Report, 3 Aug.-30 Sep. 1964

Aaron Wallace 15 Oct. 1964 113 p refs

(Contract NASw-929)

(NASA-CR-59874; KIC-RD-000162-1) OTS Prices: HC \$4.00/MF \$0.75

The laser-beam-pointing problem associated with the potential use of lasers in communications between a vehicle in deep space and an earth station is being investigated. The advantages of laser communication are based on low-power transmitters in deep space vehicles, extremely narrow bandwidths (0.01 to 1.0 arc seconds) and very wide band frequency channels that offer high information rate real-time data transmission. An analysis of the factors and variables involved in the total vehicle-ground station-environment complex shows that the presence of the earth's atmosphere in the communications link introduces additional requirements for system synthesis beyond extraordinary optical precision, due to the narrow beamwidths and the dynamics of closed loop operation with transit time effects and target-observer motions. Other progress reported includes the establishment of reference axes, investigation of techniques for measuring and positioning the laser beam, and analysis of fine beam steering and boresight maintenance. M.P.G.

1963

IAA ENTRIES

A63-10067**LASERS: A DYNAMIC NEW INDUSTRY.**

E. B. Rechsteiner (Technology Markets Inc.)

Industrial Research, vol. 4, Nov. 1962, p. 14-21.

General description of the design and the principles of operation of lasers, with emphasis on their future potentials and applications in communications, chemistry, instrumentation, metallurgy, and defense. Photos of some of the laser devices are included.

A63-10144**NOVYE DANNYE O SVOISTVAKH IZLUCHENIIA KVANTOVYKH GENERATOROV SVETA (LAZEROV) [NEW DATA ON THE PROPERTIES OF EMISSION OF QUANTUM LIGHT GENERATORS (LASERS)].**

E. V. Shpol'skii.

Uspekhi Fizicheskikh Nauk, vol. 77, July 1962, p. 553-558. In Russian.

Brief review of data on laser properties, utilizing exclusively US and British experimental results. Nonlinear effects are discussed with respect to plane-polarization light waves, and ruby lasers. Stimulated emission of organic molecules, based on certain principles formulated by Rautian and Sobel'man and Terenin and Ermolaev, is covered.

A63-10341**RUBY LASER OPERATION IN THE NEAR IR.**

E. J. Woodbury, and W. K. Ng (Hughes Aircraft Co., Culver City, Calif.)

IRE, Proceedings, vol. 50, Nov. 1962, p. 2367.

Army Contract No. DA36-039-SC88936.

Observation of a stimulated emission at approximately 7.670 \AA , accompanying the usual 6.943 \AA emission in the course of experiments with a pulsed reflector laser of the type described by Hellwarth and McClug.

A63-10342**DETECTION AND AMPLIFICATION OF THE MICROWAVE SIGNAL IN LASER LIGHT BY A PARAMETRIC DIODE.**

S. Saito, K. Kurokawa, Y. Fujii, T. Kimura, and Y. Uno (University of Tokyo, Institute of Industrial Science, Tokyo, Japan).

IRE, Proceedings, vol. 50, Nov. 1962, p. 2369, 2370.

Presentation of the results of a test of a semiconductor point-contact diode to check the possibility of detection of the microwave signal in laser light. It is concluded that some increase of junction capacitance takes place during the illumination.

A63-10343**EXPERIMENTS ON A PARTIALLY SHIELDED RUBY LASER ROD.**

R. L. Asgard (Honeywell Research Center, Hopkins, Minn.)

IRE, Proceedings, vol. 50, Nov. 1962, p. 2374, 2375.

Presentation of experimental results conducted with a partially shielded ruby-laser rod. It is shown that the pumping efficiency for the laser can be increased up to 20% at temperatures below 200°K by increasing the pumping energy per unit length, and by reducing the length pumped.

A63-10446**OPTICAL MASERS - SOME DEVELOPMENTS BY WESTINGHOUSE ELECTRIC CORPORATION.**Machinery, vol. 101, Nov. 14, 1962, p. 1106-1109.

Discussion of the development of lasers, including the principles underlying the operation of the laser, and a simplified explanation of the theory of electromagnetic absorption and emission. Some newly developed lasers are described and their performance is analyzed.

A63-10560**SPACECRAFT SENSORS.**

Charles E. White (Avco Corp., Research & Advanced Development Div., Wilmington, Mass.)

Space/Aeronautics, vol. 38, Dec. 1962, p. 70-72.

Review of the current state-of-the-art in spacecraft sensor design. Particular attention is given to the requirements of navigation- and attitude-control systems. Sensing functions, for which today's sensors are inadequate, are defined, and developments that justify the hope for better sensors in the reasonably near future are discussed.

A63-10599**ON DIFFRACTION LOSSES IN LASER INTERFEROMETERS.**

C. L. Tang (Raytheon Co., Research Div., Waltham, Mass.)

Applied Optics, vol. 1, Nov. 1962, p. 768-770.

Presentation of an approximate procedure, using a variational principle, to obtain analytic formulas for the diffraction losses of the parallel-plane, infinite-strip, and circular-disk types of interferometers. Numerical values obtained using these asymptotic formulas are given and shown to be in close agreement with the numerical results of Fox and Li.

A63-10600**PROPOSED PUMPING SCHEME FOR CONTINUOUS LASER.**

Jerome Kremen (American Instrument Co., Inc., Silver Spring, Md.)

Applied Optics, vol. 1, Nov. 1962, p. 773, 774.

Description of four laser illuminator schemes. The optimum method, by incorporating a spherical mirror, collects almost a full solid angle of light from a lamp. If, in addition, the ruby is sapphire clad and the rear of the cladding is silvered, the image may be reduced and double-passed through the rod.

A63-10644**TEST OF THE GENERAL THEORY OF RELATIVITY.**

M. Subotowicz.

Nature, vol. 196, Nov. 17, 1962, p. 628-630. 33 refs.

Proposed test of the relativistic effect of the deflection of light using artificial satellite techniques. It is suggested that an artificial satellite, equipped with a laser radiation source, in a well-defined orbit around a celestial body, can be used to measure the deflection of light in the gravitational field. The covering time of the satellite by the celestial body would be measured; as a result of the deflection of radiation emitted by the satellite, the covering time will appear to be shorter than if there were no deflection. The hypothesis is then applied to the case of a satellite with a laser radiation source, orbiting the Sun. The techniques, limitations, and advantages of the procedure are outlined.

A63-10741**ZEEMAN EFFECTS IN THE HELIUM-NEON PLANAR LASER.**

W. Culshaw, J. Kannelaud, and F. Lopez (General Telephone and Electronics Laboratories, Inc., Palo Alto, Calif.)

The Physical Review, 2nd Series, vol. 128, Nov. 15, 1962, p. 1747, 1748.

Investigation of the effect of stray or of applied magnetic fields on the modes and polarization of the planar laser output. For weak fields, the splittings are found to be small in relation to the Doppler broadening of the Ne laser transition, but the polarizations, or labeling of the photons available in the Zeeman transitions, allow simultaneous oscillation in different modes at frequencies within the same natural linewidth of the Ne atoms in the vicinity of a given axial resonance. Strong low-frequency beats are observed, arising from a splitting of a single axial resonance into two oscillations with different polarizations, which are pulled toward the centers of the respective lines. Such low-frequency beats are found to give rise, also, to a splitting of the 120 Mc axial mode beats. The multiplicity of low-frequency beats observed, particularly for small magnetic fields and high power levels, is shown to be caused by similar effects from a number of axial modes. At higher magnetic fields, relaxation oscillations similar to those which occur in the ruby laser are in evidence.

A63-10795

MODE SEQUENCES IN RUBY LASER EMISSION.

T. P. Hughes and K. M. Young (Associated Electrical Industries Research Laboratory, Aldermaston, Berkshire, England).
Nature, vol. 196, Oct. 27, 1962, p. 332-334. 10 refs.

Description of a detailed investigation, by methods similar to those employed by Hughes, of the near-field patterns and wavelengths of the first few spikes emitted by a laser operated very close to threshold conditions. Transverse-mode patterns, similar to those already reported for single spikes from ruby lasers are observed. The experiments recorded show each spike to be associated with a single mode of oscillation, in agreement with the results of Hanes and Stoicheff. In addition, however, they show that in the early spikes one or more sequences of modes occur, overlapping in time. Each sequence is associated with a certain region of the crystal face. The steady progression towards longer wavelengths noted previously is observed during a sequence. The longitudinal mode number decreases regularly by one, or sometimes two, from one member of the sequence to the next. The transverse-mode patterns do not change systematically with time, but a general trend towards more complex and extensive patterns is apparent.

A63-10826

EFFECT OF MIRROR ALIGNMENT IN LASER OPERATION.

J. F. Ready and D. L. Hardwick (Honeywell Research Center, Hopkins, Minn.)

IRE, Proceedings, vol. 50, Dec. 1962, p. 2483, 2484.

Study of the effects of parallelism of external end mirrors on the threshold for laser action for a ruby laser. The end plates of the interferometer are aligned parallel using the method of multiple images of a mercury arc. After the threshold for laser action is measured, the alignment is changed by adjustment of the end plates. The deviation from parallelism is determined by the displacement of the multiple images. It is found that the threshold is surprisingly insensitive to mirror alignment and that the minimum threshold energy does not fall at the position of most exact alignment, but occurs at a misalignment of almost one minute of arc. It is postulated that this amount of misalignment tends to correct the deviations of light rays in the ruby. It indicates the position in which the end plates are most nearly optically parallel, considering the presence of the crystal within the interferometer. No dependence is observed of the divergence of the laser output beam near threshold on the alignment of the end plates. A diagram showing the laser threshold energy vs mirror alignment is included.

A63-10827

FOCUSED SIDE PUMPING OF LASER CRYSTAL.

K. Tomiyasu (General Electric Co., General Engineering Laboratory, Schenectady, N.Y.)

IRE, Proceedings, vol. 50, Dec. 1962, p. 2488, 2489.

Study of the focused side pumping of laser crystal as found, for example, in an elliptic configuration. In this simplified analysis it is assumed that all the pump flux-propagation vectors are normal to the laser rod axis, and that the flux is constant and independent of direction of arrival. It is shown that at low energy levels, focusing in the laser rod is enhanced since the flash-lamp discharge diameter is smaller than at higher energy levels. A diagram showing the pump flux distribution inside a laser crystal is presented.

A63-10828

EFFICIENCY OF A MULTIPLE ELLIPSES CONFOCAL LASER PUMPING CONFIGURATION.

D. L. Fried and P. Eltgroth (North American Aviation, Inc., Space and Information Systems Div., Information Systems Laboratory, Torrance, Calif.)

IRE, Proceedings, vol. 50, Dec. 1962, p. 2489.

Presentation of the results of a study of an optical pumping system which uses several light sources and several truncated elliptical cylinders. It is shown that the expected improvement in ability to concentrate large amounts of light at the absorber is nonexistent. It is found that, while large eccentricity in the ellipse increases the angle over which light would be gathered and focused in each of the truncated ellipses, it has the disadvantage of increasing the spread of the image. In order to demonstrate the significance of the eccentricity relationships are tabulated between the semimajor axis, semiminor axis, the eccentricity, and the percentage of the light gathered when the ellipse is so truncated as to allow four light sources to pump one laser rod.

A63-10897

ORGANOMETALLIC COMPOUNDS AS POSSIBLE LASER MATERIALS.

Erhard J. Schimitschek and Erich G. K. Schwarz (General Dynamics Corp., Astronautics Div., San Diego, Calif.)
Nature, vol. 196, Dec. 1, 1962, p. 832, 833.

Proposal for the use of organometallic rare-earth compounds for laser actions. A molecular system capable of absorption over a broad spectral band, in conjunction with sharp emission lines, is desired in order to obtain laser action at higher power outputs than are presently accessible. Various covalent organic compounds of europium, samarium, and terbium have been reported to show the desired behavior. Organic constituents of these compounds contain one or two substituted benzene rings, such as salicylaldehyde for each of the three covalent bonds formed with the rare-earth atom. The three-step process of optical absorption and emission in these compounds is discussed. Absorption (step 1) occurs in a broad, quasi-continuous, UV band in the region between 300-4,000 Å, and is dominated by the organic constituent of the complex molecule. The intramolecular energy transfer (step 2) occurs without radiation, and is highly dependent on temperature. At liquid-nitrogen temperatures, transfer efficiencies as high as 85% have been observed. The re-emission of excitation energy (the final step) is fully radiative. It shows the sharp fluorescence spectra characteristic of the rare-earth atom, but is modified somewhat by the nature of the organic constituent. The organometallic rare-earth compounds have attractive optical properties. An estimate of pump power required to start laser oscillation, using europium salicylaldehyde as an example, is given as 8.5 w. Photodecomposition under intense UV radiation is indicated as a possible obstacle to the experimental realization of organometallic compounds as laser materials.

A63-10944

HIGH GAIN GASEOUS (Xe-He) OPTICAL MASERS.

C. K. N. Patel, W. L. Faust, and R. A. McFarlane (Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

Applied Physics Letters, vol. 1, Dec. 1, 1962, p. 84, 85.

Description of a gaseous maser medium, containing a mixture of helium and xenon, capable of large optical amplification at a wavelength of 2,026 μ. It yields an optical gain as high as 4.5 db/m. An enormous increase in the optical gain is obtained by the addition of relatively large amounts of helium to xenon.

A63-10945

SEMICONDUCTOR MASER OF GaAs.

T. M. Quist, R. H. Rediker, R. J. Keyes, W. E. Krag, B. Lax, A. L. McWhorter, and H. J. Zeigler (Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.)

Applied Physics Letters, vol. 1, Dec. 1, 1962, p. 91, 92.

Description of semiconductor maser experiments which produced coherent radiation from GaAs diodes at 77°K and greatly improved performance at 4.2°K. It is believed that at 4.2°K in the linear region well above threshold, the maser is operating at nearly unity quantum efficiency - i.e., that for every electron crossing the junction, nearly one photon is emitted. A full confirmation will require an absolute measurement of the light output.

A63-10963

OPTICAL MASERS.

J. H. Sanders (Oxford University, Oriel College, Clarendon Laboratory, Oxford, England).

(British Institution of Radio Engineers, Symposium on Masers and Lasers, London, England, Jan. 2, 1963.)

British Institution of Radio Engineers, Journal, vol. 24, Nov. 1962, p. 365-372. 12 refs.

Review of optical masers, with emphasis on the principle of the maser and its extension to the IR and visible region of the spectrum. Various types of optical maser which have been successfully operated are described. The unique features of high spectral purity and narrow beamwidth are pointed out, and some present and future applications are considered.

A63-10990

PRINCIPAL USES OF COHERENT LIGHT.

H. Bosc (Laboratoire Central de Télécommunications, Paris, France).

Electrical Communication, vol. 37, no. 4, 1962, p. 360-366.

Discussion of factors to be considered in the application of coherent light to communication, radar, energy concentration, and long-range transfer. The laser is considered the most attractive source of coherent light. Coherent light may be used as a carrier permitting transmission of information by means of modulation. The high directivity of the beam makes possible long-distance links with small power and long-range energy transfer with good efficiency. A monochromatic light beam emitting plane waves can be concentrated by optical means in a spot of approximately 1λ , making possible considerable energy densities. Such fields may provoke interactions with matter such as, nonlinear effects, and the frequency-multiplication phenomenon. Intense and localized thermal effects can also be obtained in this manner, making possible localized chemical reactions and welds of very small dimensions for use in microminiaturization applications.

A63-10991

LASERS.

M. Pauthier (Laboratoire Central de Télécommunications, Paris, France).

Electrical Communication, vol. 37, no. 4, 1962, p. 377-386.

Discussion of the outstanding characteristics of the laser as they may appear to the radio electrician. It is concluded that the main advantages of laser devices - i. e., the space and time coherences of the emitted radiation, are basically determined by the properties of the cavity used. The reason for this is the greater sharpness of this cavity compared to the width of the transition used. As long as this remains true, it is reasonable to say that the laser is as good as the cavity.

A63-11035

AEROSPACE ELECTRONICS; ADVANCED COMMUNICATIONS - OPTICAL COMMUNICATIONS.

K. W. Otten (National Cash Register Co., Dayton, Ohio).

Space/Aeronautics, pt. 2, Technical Reference Series, Nov. 1962, p. 63, 64, 66.

Evaluation of the applicability of optical systems to long-distance space communications. Beam-directing devices, known laser materials, liquid Kerr cells, and laser heterodyne receivers are discussed.

A63-11092

DETECTION OF LASER RADIATION.

Vincent J. Corcoran and Yoh-Han Pao (University of Chicago, Laboratories for Applied Sciences, Chicago, Ill.)

Optical Society of America, Journal, vol. 52, Dec. 1962, p. 1341-1350.

Contract No. AF 33(616)-7095.

Determination of the magnitudes and frequencies of the fluctuations in electron emission from the photosurface associated with the photon noise and shot noise. The parameters which affect these magnitudes are established. The influence of the fluctuations upon the probability of detecting low-level laser radiation is examined.

A63-11200

LIGHTNING STRIKES MANUFACTURING - ELECTRICAL MATERIAL-WORKING PROCESSES.

T. W. Black.

Tool & Manufacturing Engineer, vol. 50, Jan. 1963, p. 87-94, 12 refs.

Description of several methods of metal working and forming in which electrical energy is used directly to cut or shape materials to final size and form. Among the procedures considered are the following: electrical-discharge, electrochemical, electron-beam, and electro-optical machining, and electrohydraulic and electromagnetic forming. Specific applications of each of these processes are discussed and illustrated.

A63-11301

EFFICIENCY OF VARIOUS PUMPING SYSTEMS IN RUBY TRAVELING - WAVE MASERS.

V. B. Shteinsleiger, G. S. Mizezhnikov, and O. A. Afanas'iev. (Radiotekhnika i Elektronika, vol. 7, May 1962.)

Radio Engineering and Electronic Physics, vol. 7, May 1962, p. 828-833. Translation.

Comparison between three possible working systems of quantum-mechanical, paramagnetic ruby amplifiers, using a different quantum transition for amplifiers, and a different quantum transition for pumping. The dependence of the amplification coefficient of traveling-wave, quantum mechanical paramagnetic amplifiers on chromium concentration and temperature is investigated in these systems.

A63-11415

OPTICAL DATA PROCESSING.

James McDermott.

Space/Aeronautics, vol. 39, Jan. 1963, p. 79-85.

Summary of new developments in digital data processing resulting from the invention of the laser and the use of fiber optics. Methods of combining lasers to form logic devices are shown, along with the possibilities that they hold for all optical data processing. The new solid-state injection laser, more electronic than optical, is described, with a forecast of its applications. Fiber optics for logic systems, memories, and data display are analyzed, and a review is given of electroluminescent-photoconductive (EL-PC) cells in the basic functions of digital data processing.

A63-11431

THE COHERENCE AND DIRECTIVITY OF EMISSION FROM A RUBY LASER.

M. D. Galanin, A. M. Leontovich, and Z. A. Chizhikova.

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 43, July 1962, p. 347-349.)

Soviet Physics - JETP, vol. 16, Jan. 1963, p. 249-251. Translation.

Experimental investigation of the relation between coherence and directivity of ruby-laser emission. It is shown that emission pulsations during generation arise simultaneously in all radiating surfaces of the crystal. Interference experiments indicate that almost the entire end face of the crystal radiates coherently, but that the wave front is not plane. It is also observed that there is no connection between the ring emission pattern of some crystals and their coherence.

A63-11834

METODY SUZHENIIA SPEKTRAL'NYKH LINII DLIA INTERFERENTSIONNYKH IZMERENII DLIIN [METHODS OF NARROWING SPECTRAL LINES FOR THE INTERFERENTIAL MEASUREMENT OF LENGTH].

A. P. Kirichenko.

Uspekhi Fizicheskikh Nauk, vol. 78, Nov. 1962, p. 525-538, 29 refs. In Russian.

Description of methods for obtaining strictly monochromatic radiation narrower than that of Doppler. Methods covered are the following: (1) interference monochromatization, usually applied to emission lines located in the visible region of the spectrum; (2) absorption monochromatization for resonance lines located in the UV region of the majority of elements; and (3) methods of obtaining intensive coherent radiations by means of lasers; and (4) a method of obtaining narrow coherent radiation by means of interference-compensation circuits.

A63-11878

FLUORESCENCE IN CdS AND ITS POSSIBLE USE FOR AN OPTICAL MASER.

D. G. Thomas and J. J. Hopfield (Bell Telephone Laboratories, Inc., Murray Hill, N.J.)

Journal of Applied Physics, vol. 33, Nov. 1962, p. 3243-3249.

Consideration of fluorescence from semiconductors for possible use in constructing a laser. Attention is given to the sharp-line emission which occurs at low temperatures in cadmium sulfide and which arises from excitons bound to impurities. Some recent experimental results are summarized which give information concerning the fluorescent efficiency and the depth to which crystals are excited using UV light for excitation. Possible laser geometries are discussed, and the opportunities for using an evacuated ground state are pointed out. There appear to be several severe difficulties associated with the small depth of penetration of the exciting light, with the low fluorescent efficiencies available, and with the inability to grow large perfect crystals with controlled impurity content. With CdS, both phonon and Zeeman effects can

be used to produce depopulation. The effects are briefly discussed. It is indicated that an improvement in the art of crystal growing is probably necessary before the effects described can be expected to result in a useful laser.

A63-11983

ADVANCED ELECTRON TUBES FOR HIGH FREQUENCY, HIGH POWER, AND LONG LIFE.

Walter L. Knecht (USAF, Systems Command, Aeronautical Systems Div., Electronic Technology Laboratory, Wright-Patterson AFB, Ohio).

(American Society of Metals, Golden Gate Conference, San Francisco, Calif., Feb. 1962.)

IN: Materials Science and Technology for Advanced Applications. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962, p. 467-497.

Discussion of new developments in submillimeter and millimeter tubes. Five categories of microwave tubes are tabulated; M-type backward-wave oscillators, klystrons, magnetrons, TWT, and O-type backward-wave tubes. Two relatively new high-power submillimeter-tube approaches are reviewed; the ubitron and the rebatron. Also considered are the tornadotron device, lasers, electron-beam plasma interaction, and optical-grating interaction.

A63-12077

PULSED OPTICAL LASER RADAR.

Robert D. Kroeger.

Sperry Engineering Review, vol. 15, Winter, 1962, p. 44-53.

Description of a pulsed laser radar, and presentation of several examples that demonstrate the radar's range and angular resolution capabilities for observations made near the horizon in daylight. Two versions of Q-switched lasers are described. Concepts of two systems are discussed. In one, the target is measured by electronic scanning; and in the other, the target is illuminated and imaged using the laser's high-power density. Both depend upon the laser's narrow-beam capability. To demonstrate the capability of the radar, a typical ranging system is analyzed, in which, with the radar located on the ground, the SNR is computed for nighttime ranging on an Echo-type satellite 1,000 miles away.

A63-12276

NEW EXPERIMENTAL TESTS OF THE SPECIAL PRINCIPLE OF RELATIVITY.

C. Møller (Universitetets Institut for Teoretisk Fysik, and Nordisk Institut for Teoretisk Atomfysik, Copenhagen, Denmark).

Royal Society (London), Proceedings, Series A, vol. 270, Nov. 27, 1962, p. 306-311; Discussion, p. 311-314. 19 refs.

Presentation of data from tests, performed by means of two masers with the molecular beams in opposite directions, to provide direct experimental information for Einstein's principle of relativity. It is assumed that the characteristic frequency of the maser is determined as a certain mean value of the Doppler frequency over different directions of emission.

A63-12293

THE LASER.

A. Yariv and J. P. Gordon (Bell Telephone Laboratories, Inc., Murray Hill, N.J.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 4-29. 105 refs.

Review of the field of lasers, summarizing both theory and practice. Blackbody radiation theory is used to introduce the concepts of spontaneous and induced transitions. The Schawlow-Townes instability (start-oscillation) condition is derived, and the different laser media are described. Other topics treated include optical pumping, experimental techniques, output power, noise, optical resonators, and lasers in communications.

A63-12294

THE POTENTIALITIES AND PRESENT STATUS OF MASERS AND PARAMETRIC AMPLIFIERS IN RADIO ASTRONOMY.

J. V. Jelley (Atomic Energy Research Establishment, Nuclear Physics Div., Harwell, Berkshire, England).

IEEE, Proceedings, vol. 51, Jan. 1963, p. 30-45. 113 refs.

Review of the potentialities and present status of maser and parametric radiometer systems in the field of radio astronomy. A short historical account of the development of the maser is followed by an outline of the objectives of radio-astronomical research and the radiation mechanisms which arise. The requirements of the radio astronomer are noted, and a detailed discussion is presented of the limitations and relative merits of masers and parametric amplifiers in radio astronomy. A compilation of data on existing and planned observatory installations is included. There is also a brief summary of some achievements in astronomy which have resulted directly from the developments and applications of these low-noise devices. Likely trends in the near future are indicated.

A63-12295

CHARACTERISTICS OF GIANT OPTICAL PULSATIONS FROM RUBY.

F. J. McClung and R. W. Hellwarth (Hughes Research Laboratories, Malibu, Calif.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 46-53. 10 refs. Contract No. AF 33(616)-8233.

Description of a method of laser modulation which produces fast, intense, and controllable giant laser pulses by Q-modulation. The principles of the technique are outlined and early experimental results reviewed. The temporal, spectral, and spatial structure of giant pulses produced from ruby by a nitrobenzene Kerr-cell modulator is reported. The pulse characteristics found to date yield information about the nature of various relaxation processes in ruby. Results of experiments show the following: (1) a shortening of upper-state relaxation time by about seven times under heavy pumping; (2) relaxation of excitation taking place across the laser line in microseconds; (3) progressive spectral broadening for shorter pulses to encompass most of the fluorescent line; (4) increasing asymmetry of spectral output for faster, more intense pulses; and (5) little broadening of beam divergence over normal, but with added structure.

A63-12296

HOLMIUM DOPED CALCIUM FLUORIDE AS A MASER MATERIAL.

E. S. Sabisky and H. R. Lewis (Radio Corporation of America, RCA Laboratories, Princeton, N.J.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 53-56. 13 refs. Contract No. DA36-039-sc-87386.

Discussion of the use of the large magnetic interaction between the nucleus and the paramagnetic electrons found in rare-earth ions, particularly holmium. A three-level microwave maser requires that transitions be allowed between nonadjacent energy levels. The requirement can be satisfied by a strong hyperfine interaction which, like a noncubic crystalline field, mixes the spin states. Moreover, an energy doublet in a cubic field would have an isotropic Zeeman effect and the material could then be used in powdered form. EPR (Electron Paramagnetic Resonance) studies show that divalent holmium in CaF_2 is such a material. It is shown that $\text{Ho}^{2+}:\text{CaF}_2$ is expected to have a figure of merit which is 0.1 that of ruby for equal concentrations of the paramagnetic ion.

A63-12297

URANIUM-DOPED CALCIUM FLUORIDE AS A LASER MATERIAL.

J. P. Wittke, Z. J. Kiss, R. C. Duncan, Jr., and J. J. McCormick (Radio Corporation of America, RCA Laboratories, Princeton, N.J.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 56-62. 10 refs. Contract No. AF 33(616)-8199.

Spectroscopic study of the $\text{U}^{3+}:\text{CaF}_2$ system, and of its behavior as an optical maser. The results show that, apart from a set of absorption lines due to tetravalent uranium, the $\text{U}:\text{CaF}_2$ crystals exhibit two types of U^{3+} sites. An energy level system is determined for the sites corresponding to "isolated" ions. These sites give rise to a maser transition at 2.5μ . The second type of site, appearing only in more highly doped crystals, is associated with the maser lines observed at 2.61 and 2.57μ .

A63-12298

ZEEMAN EFFECTS IN GASEOUS He-Ne OPTICAL MASERS.
R. Paananen, C. L. Tang, and H. Statz (Raytheon Co., Research Div., Waltham, Mass.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 63-69.

Experimental and theoretical study of the Zeeman effects in a gaseous He-Ne laser under weak and normal excitation conditions. Attention is confined to the strongest maser emission line ($2s_2 \rightarrow 2p_4$). Under weak excitation conditions, the maser emission is a doublet of right and left circularly polarized waves. These may belong either to the same cavity mode or to different cavity modes, depending on the strength of the applied magnetic field. When viewed through a linear polarizer, the maser emission is amplitude modulated. Under normal excitation conditions, for suitable magnetic fields, the maser could oscillate in at least three modes. The maser emission would then consist of a pair of right circularly polarized waves of two different cavity-resonant frequencies and a pair of left circularly polarized waves of different frequencies. In this case, a beat note at the difference frequency is photo-detected without the need of a linear polarizer.

A63-12300

SEMICLASSICAL TREATMENT OF THE OPTICAL MASER.

L. W. Davis (Philco Corp., Western Development Laboratories, Palo Alto, Calif.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 76-80. 10 refs.

Study, on the basis of the semiclassical theory of radiation, of the steady-state operation of the laser oscillator for the case in which a single cavity mode is excited. With the introduction of certain simplifying assumptions, calculations yield concise results for the frequency and amplitude of the field oscillations. A frequency pulling effect is predicted which corresponds to the Block-Siegert shift or which, alternatively, may be regarded as the result of the Stark effect.

A63-12301

MODES IN A MASER INTERFEROMETER WITH CURVED AND TILTED MIRRORS.

A. G. Fox and Tingye Li (Bell Telephone Laboratories, Inc., Holmdel, N.J.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 80-89.

Extension of a study on an idealized interferometer, emphasizing the effects of certain simple forms of aberration. The first type of aberration is represented by tilted plane mirrors, and the second by curved mirrors. Tilting the mirror causes the mode patterns to become asymmetric and the diffraction loss to become greater. It also tends to equalize the losses of the two lowest-order modes, thus causing a beating phenomenon which is observed experimentally. In the case of interferometers with mirrors of arbitrary radii of curvature, there exist regions of low loss and high loss as the mirror spacing is varied. The loss function is represented by a contour map of a three-dimensional model which has certain symmetry properties. This model is useful in choosing proper mirror spacing for low-loss operation of optical masers.

A63-12302

COMPARISON OF QUANTUM AND SEMICLASSICAL RADIATION THEORIES WITH APPLICATION TO THE BEAM MASER.

E. T. Jaynes (Washington University, St. Louis, Mo.) and F. W. Cummings (Ford Motor Co., Aeronutronic Div., Newport Beach, Calif.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 89-109. 17 refs.

Clarification of the relationship between the quantum theory of radiation in which the electromagnetic field-expansion coefficients satisfy commutation relationships, and the semiclassical theory in which the electromagnetic field is considered as a definite function of time rather than as an operator. Some of the results are applied to the study of amplitude and frequency stability in a molecular beam maser. It is shown that the semiclassical theory, when extended to take into account both the effect of the field on the molecules and the effect of the molecules on the field, reproduces almost quantitatively the same laws of energy exchange and coherence properties as the quantized field theory. In particular, the semiclassical theory is shown to lead to a prediction of spontaneous emission, with the same decay rate as that given by quantum electrodynamics. Equilibrium amplitude and

frequency of oscillation are obtained for an arbitrary velocity distribution of focused molecules, generalizing the results obtained previously by Gordon, Zeiger, and Towns for a single-velocity beam, and by Lamb and Helmer for a Maxwellian beam. The effect of amplitude and frequency of oscillation is calculated for small systematic perturbations. The response of an oscillating maser to randomly time-varying perturbations is considered. Graphs are given showing predicted response to a small, superimposed signal of a frequency near the oscillation frequency. The existence of noise-enhancing and noise-quieting modes of operation is shown to be a general property of any oscillating system in which amplitude is limited by nonlinearity.

A63-12303

PARAMETRIC AMPLIFICATION IN SPATIALLY EXTENDED MEDIA AND APPLICATION TO THE DESIGN OF TUNEABLE OSCILLATORS AT OPTICAL FREQUENCIES.

Norman M. Kroll (University of California at San Diego, La Jolla, Calif.)

(Physical Review, vol. 127, Aug. 1962, p. 1207-1211.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 110-114.

Development of a theory of traveling- and backward-wave, variable-parameter amplification appropriate to the amplification of a light beam. It is an extension of the theory of Tien and Suhl for one-dimensional propagation to the case in which the pump wave, signal wave, and idler waves have different directions of propagation. The theory is then applied to the design of a tuneable oscillator at optical wavelengths. The device is tuned by changing the orientation of a parallel-mirror system. It appears that currently available pulsed-laser powers are sufficient to drive such devices, and that a continuous tuning range over a three-to-one interval in frequency is possible.

A63-12304

MASERS AND MILLIMETER WAVES.

Frank S. Barnes (University of Colorado, Electrical Engineering Dept., Boulder, Colo.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 115-119. 43 refs.

University of Colorado Research Council, and National Engineering Science Co. supported research.

Review of the characteristics of a number of different kinds of masers to estimate their usefulness in the wavelength region between one and 0.1 mm. An estimate of the maximum power output for these systems is made and compared with the output to be expected from mixing two optical signals in a nonlinear dielectric and on a photocathode. Additionally, the noise characteristics of maser amplifiers are briefly reviewed for this region of the spectrum.

A63-12305

AN ACTIVE INTERFERENCE FILTER AS AN OPTICAL MASER AMPLIFIER.

Vern N. Smiley (U.S. Navy, Electronics Laboratory, San Diego, Calif.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 120-124. 12 refs.

Derivation of approximate theoretical expressions for gain, bandwidth, and root gain-bandwidth by introducing negative absorption into equations for a Fabry-Perot interference filter. Results of gain vs frequency calculations are given for a 10-cm maser with high single-pass gain and a 100-cm maser with low single-pass gain. Root gain-bandwidth is shown to be a constant for a given cavity as long as the cavity bandwidth is much smaller than the Doppler or fluorescent linewidth of the maser transition. Frequency drift due to temperature variations and the necessity for precise control of single-pass gain are two practical problems. These must be solved in order to make a stable amplifier with high gain.

A63-12307

WIDE-BAND MICROWAVE LIGHT MODULATION.

W. W. Rigrod (Bell Telephone Laboratories, Inc., Murray Hill, N.J.) and I. P. Kaminow (Bell Telephone Laboratories, Inc., Holmdel, N.J.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 137-140. 10 refs.

Description of a method for obtaining light modulation of an extremely wide band by traveling-wave interaction in electro-optic or magneto-optic materials. When the intrinsic velocity of microwaves in the material is appreciably less than that of light, the synchronism conditions require the light to be directed obliquely with respect to the wave vector of the microwave field. Structures are described which satisfy this condition, and in which the microwave field is largely concentrated in the electro-optic medium, resulting in very little dispersion and economical use of microwave power. The use of the linear electro-optic effect in potassium dihydrogen phosphate in such applications is considered.

A63-12309**GIGACYCLE BANDWIDTH COHERENT LIGHT TRAVELING-WAVE PHASE MODULATOR.**

C. J. Peters (Sylvania Electric Products, Inc., Sylvania Electronic Systems, Applied Research Laboratory, Waltham, Mass.)
IEEE, Proceedings, vol. 51, Jan. 1963, p. 147-153.

Description of a continuous-duty, coherent-light phase modulator which exhibits a bandwidth in the gigacycle range. A modulation index of unity is obtained with a modulation peak power of about 12 watts. This power level is independent of the bandwidth of the modulation. The extremely wide bandwidth operation with the low modulation power is obtained by applying the modulation voltage to the electro-optical material by means of a traveling-wave structure of the transmission-line type. The direction of propagation of the light and of the modulation are colinear and the transmission line is designed so that the light progresses through the crystal in synchronization with the modulation on the line. The magnitude of the angular modulation is determined by illuminating the modulator with a ruby laser and examining the individual spectral components of the output with an S-band, traveling-wave, microwave phototube receiver. Similar to the behavior of conventional FM systems, a minimum in the carrier at a modulation index of 3.75 is observed as well as the appearance of the appropriate sidebands. These experiments are performed at 30 Mc and 1 Gc. The attenuation of the 1 Gc modulation through the modulator and the balun at either end is 2 db, and the attenuation of the light through the electro-optical crystals is about 6 db.

A63-12312**INDUCED γ -RAY EMISSION.**

V. Vali and W. Vali (Boeing Co., Boeing Scientific Research Laboratories, Seattle, Wash.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 182-184.

Extension of optical maser techniques to the gamma-ray region. It is shown that under certain conditions induced gamma rays can be produced. The condition of criticality rather than that of oscillation is used because a gamma-ray maser does not have a resonant structure. The main observable effects are the shortening of lifetimes of some gamma excitations and the appearance of two or more coherent gamma quanta.

A63-12313**OPTICAL PUMPING OF MICROWAVE MASERS.**

H. Hsu and F. K. Tittel (General Electric Co., Electronics Laboratory, Syracuse, N.Y.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 185-189. 13 refs.
Contract No. DA-36-039-sc-87209.

Discussion of the application of optical pumping techniques to microwave masers. It is shown that optical pumping appears to be promising for achieving low-noise maser action at very high frequencies and at elevated temperatures. The analysis includes the treatment of optical-pumping principles, noise considerations, pump-power requirements, and maximum signal frequencies. Potential advantages and limitations which can exist when using optical excitation are considered. The developed concepts and procedures are applied for illustrative purposes to evaluate the expected performance of a ruby maser.

A63-12314**REQUIREMENTS OF A COHERENT LASER PULSE-DOPPLER RADAR.**

G. Biernson and R. F. Lucy (Sylvania Electric Products, Inc., Sylvania Electronic Systems, Applied Research Laboratory, Waltham, Mass.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 202-211. 10 refs.

Description of the requirements and performance of coherent, optical detection in an optical radar application, comparing the coherent with noncoherent detection. An important requirement to achieve such a system is the development of an efficient laser transmitter having a high-power pulse laser (or less than 10- μ sec pulse width) driven by a CW-laser oscillator which supplies the coherent local-oscillator reference. It is indicated that such a transmitter will probably be available in the near future, and coherent-laser radar systems will then be practical. It is shown that to achieve an efficient coherent optical radar, a pulse width less than 10- μ sec and a spectral line width less than 10 Mc is required.

A63-12316**QUANTUM ELECTRODYNAMIC PREDICTION OF THE ENVELOPE MODULATION OF MASER BEAMS.**

R. M. Bevensee (University of California, Electrical Engineering Dept., Berkeley, Calif.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 215, 216.

Derivation of two differential equations for a maser, one for the variation of the second-order magnetic-field energy with time and the other for the variation of the molecular energy with time. The development is based on an interpretation of the work of Senitzky. The two equations describe qualitatively the envelope modulations often observed in laser beams. It is assumed that a single cavity mode interacts (through magnetic dipole coupling) with molecules making transitions between two energy states. The slow dissipation of power from the cavity is also taken into account. As a result an envelope modulation given by the zero-order Bessel function is obtained.

A63-12317**SOVIET LASER RESEARCH.**

Simon Kassel.

IEEE, Proceedings, vol. 51, Jan. 1963, p. 216-218. 36 refs.

Brief review of Soviet achievements in the field of laser devices gleaned from the open Soviet professional literature, mainly in the field of theory. The discussion covers early research, paramagnetic materials, IR gas masers, and semiconductor IR and optical masers.

A63-12318**LASER Q SPOILING EFFECTS USING A REMOTE REFLECTOR.**

J. I. Masters and J. H. Ward (Technical Operations Research, Inc., Burlington, Mass.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 221-223.

Contract No. AF 19(628)-405.

Description of a technique for peak-power enhancement of pulsed lasers, referred to as "Q spoiling." A peak-power increase is observed when an active rod that is totally reflecting on one end is provided with a carefully aligned, remote but fixed mirror as the opposing reflector of the laser enclosure. The mechanism that appears to be effective is a simultaneous increase with mirror displacement of both the Q of the enclosure and its pre-oscillation losses. A diagram showing peak power gain vs displacement of a 90% reflector is included.

A63-12319**AN S-BAND TRAVELING-WAVE MASER.**

H. B. Yin, L. C. Morris, and D. J. Miller (Radio Corporation of America, Defense Electronics Products, Camden, N.J.)

IEEE, Proceedings, vol. 51, Jan. 1963, p. 225.

Brief description of a new S-band, traveling-wave maser with an extremely wide tunable range (2 to 3 Gc). The slow-wave circuit is a copper meander line, photoetched on a mylar substrate. Ferrite isolation techniques are used to determine the optimum location for circular polarization. Some of the experimental results obtained with this device are presented.

A63-12386**LASER FABRICATES SPACE-AGE MATERIALS.**

M. D. Weisinger (General Dynamics Corp., Convair Div., San Diego, Calif.)

SAE Journal, vol. 71, Feb. 1963, p. 56-58.

Discussion of the application of lasers to industrial needs, including machining, trimming, and welding. The operation of a laser is described. Schematic diagrams of a pulsed ruby laser and of the energy levels of the excited ruby are included.

A63-12503**CORRELATION OF OUTPUT SPIKES FROM DIFFERENT PORTIONS OF A RUBY LASER.**

J. F. Ready (Minneapolis-Honeywell Regulator Co., Honeywell Research Center, Hopkins, Minn.)

Applied Optics, vol. 2, Feb. 1963, p. 151, 152.

Experimental investigation for the purpose of correlating the oscillatory outputs from different sections of a ruby laser. Measurements made on five ruby rods with partially transmitting, aluminized coatings on the flat ends, used in a helical configuration in which the ruby was cooled by flowing gas, showed typical relaxation oscillation spikes in the laser emission. A typical trace on a dual-beam oscilloscope of the two photomultiplier outputs is presented. It is found that the relative amplitudes of the spikes are generally the same on both traces; frequently, large spikes are to be observed on one trace while the corresponding spikes on the other trace are small. Different areas are also found to contribute at different relative levels of intensity as the input energy is changed. It is surmised that the coupling between the different volumes of the ruby undergoing stimulated emission is provided by scattered laser light.

A63-12539**A LASER DESIGN FOR SPACE COMMUNICATIONS.**

Lawrence Goldmuntz (TRG, Inc., Syosset, N.Y.)

(Institute of Radio Engineers, International Convention, New York, N.Y., Mar. 26-29, 1962.)

1962 IRE International Convention Record. Part 5 - Aerospace and Navigational Electronics; Military Electronics; Radio Frequency Interference; Space Electronics and Telemetry, vol. 10, p. 298-305. Price of entire volume (332 p.): nonmembers, \$6.00.

Discussion of performance characteristics, in various missions, of simple laser systems employing both incoherent and coherent detection. Some techniques being developed to achieve coherence in time and space on the detecting element are described. It is shown that with a perfect optical heterodyne (coherent optical detector) it is possible to achieve a radiation-limited system, almost independent of the practical background likely to be encountered. Specifically, a communication system can be radiation-limited, as long as the local oscillator signal is sufficiently intense to provide a photocurrent larger than the background-derived current caused by detector noise or background radiation.

A63-12631**THE PROTON MAGNETIC RESONANCE OSCILLATOR, A RADIO FREQUENCY SOURCE OF HIGH SPECTRAL PURITY.**

Alexander Ganssen (National Co., Inc., Malden, Mass.)

(Institute of Radio Engineers-National Bureau of Standards-American Institute of Electrical Engineers-National Science Foundation, International Conference on Precision Electromagnetic Measurements, Boulder, Colo., Aug. 14-17, 1962.)

IRE Transactions on Instrumentation, vol. I-II, Dec. 1962, p. 166-170.

USAF-supported research.

Experimental investigation of some basic properties of a proton maser, making use of the dynamic Overhauser effect for population inversion and enhancement. The long proton spin relaxation times of liquid samples, in the order of seconds, facilitate the production of self-sustained continuous oscillation with high spectral purity. Theoretically, the proton maser oscillator should have a spectral purity of some parts in 10^{14} for an inhomogeneously broadened proton resonance absorption linewidth of 100 cps at a frequency of 15 Mc. A proton maser is operated at this frequency in a temperature-stabilized permanent magnet. In preliminary experiments a frequency drift in the order of one part in 10^9 /sec is measured. The spectral purity is tested by beating together the frequencies of two proton maser oscillators operating within the same magnetic field. Preliminary results yield frequency deviations of less than six parts in 10^{10} . The sources introducing frequency instability are discussed, and their relative contributions are evaluated.

A63-12632**THE ATOMIC HYDROGEN MASER.**

Norman F. Ramsey (Harvard University, Cambridge, Mass.)

(Institute of Radio Engineers-National Bureau of Standards-American Institute of Electrical Engineers-National Science Foundation, International Conference on Precision Electromagnetic Measurements, Boulder, Colo., Aug. 14-17, 1962.)

IRE Transactions on Instrumentation, vol. I-II, Dec. 1962, p. 177-182. 15 refs.

Description of the atomic hydrogen maser and experiments made with it. In this device, hydrogen atoms in the upper hyperfine state are focused onto the entrance aperture of a Teflon-coated quartz bulb in which the atoms are stored for about a second. This bulb is surrounded by a cylindrical RF cavity. When the cavity is tuned to the hyperfine frequency of atomic hydrogen, maser radiation is produced. Because of the large line Q (quality factor of the cavity) resulting from the long storage time, the radiation is highly stable in frequency. Results are given of the theoretical calculations of the threshold flux of atoms required for maser oscillations, of the various relaxation processes that limit the effective storage time, and of the possible sources of frequency shifts of the maser. The relative stability of two hydrogen masers is calculated.

A63-12633**HYDROGEN CYANIDE MOLECULAR BEAM-TYPE MASER.**

D. Marcuse (Bell Telephone Laboratories, Inc., Holmdel, N.J.)

(Institute of Radio Engineers-National Bureau of Standards-American Institute of Electrical Engineers-National Science Foundation, International Conference on Precision Electromagnetic Measurements, Boulder, Colo., Aug. 14-17, 1962.)

IRE Transactions on Instrumentation, vol. I-II, Dec. 1962, p. 187-190.

Description of a hydrogen-cyanide molecular-beam-type maser, which has been successfully operated as an oscillator. The maser, oscillating at two lines of a hyperfine triplet at 88.633 Gc, uses an interferometer-type, confocal, resonant cavity. Many molecular beams eject from two circular-beam sources radially toward the center of the circle where the cavity is located. The focusers, which separate molecules in the first excited state of the rotational energy spectrum from those in the ground state, consist of two planes. Each plane is composed of radially arranged rods which are charged alternately to high positive and high negative potentials.

A63-12634**AMMONIA MASERS.**

Koichi Shimoda (University of Tokyo, Tokyo, Japan)

(Institute of Radio Engineers-National Bureau of Standards-American Institute of Electrical Engineers-National Science Foundation, International Conference on Precision Electromagnetic Measurements, Boulder, Colo., Aug. 14-17, 1962.)

IRE Transactions on Instrumentation, vol. I-II, Dec. 1962, p. 195-200. 16 refs.

Description of operating characteristics of ammonia masers on the 3, 2 line of $N^{14}H_3$ and on the line $N^{15}H_3$. Experimental and theoretical results on the stability, resettability, and mutual consistency of ammonia masers are discussed. A method of manual tuning of the cavity by the magnetic perturbation of about 2 oersted on the 3, 2 line of $N^{14}H_3$ ensures that the frequency can be reset within a few parts in 10^{11} . A system of automatic cavity tuning for a pair of masers is found which allows higher accuracy. Various types of frequency shifts and fluctuations are considered, and methods of reducing them are discussed. Numerical evaluations of the stability and reproducibility of the ammonia maser are compared with the hydrogen maser.

A63-12635 **$N^{15}H_3$ DOUBLE-BEAM MASER AS A PRIMARY FREQUENCY STANDARD.**

Jean De Prins (University of Brussels, Brussels, Belgium)

(Institute of Radio Engineers-National Bureau of Standards-American Institute of Electrical Engineers-National Science Foundation, International Conference on Precision Electromagnetic Measurements, Boulder, Colo., Aug. 14-17, 1962.)

IRE Transactions on Instrumentation, vol. I-II, Dec. 1962, p. 200-203. 10 refs.

Experimental investigation of the use of ammonia masers as frequency standards. The masers oscillate on the $J = K = 3$ inversion line of $N^{15}H_3$. Single-beam masers allow the realization of a frequency standard with a stability of $2-3 \cdot 10^{-11}$, and an accuracy of about 10^{-9} . Experiments on double-beam masers suggest that their use makes it possible to obtain a stability of the order of 10^{-12} and an accuracy better than 10^{-10} .

A63-12636

CHARACTERISTICS OF THE 3-2 LINE DOUBLE-BEAM MASER OF $N^{14}H_3$ AND THE PRECISION OF FREQUENCY COMPARISON. Y. Saburi, M. Kobayashi, Y. Yasuda, and K. Harada (Ministry of Posts and Telecommunication, Tokyo, Japan). (Institute of Radio Engineers-National Bureau of Standards-American Institute of Electrical Engineers-National Science Foundation, International Conference on Precision Electromagnetic Measurements, Boulder, Colo., Aug. 14-17, 1962.) IRE Transactions on Instrumentation, vol. I-11, Dec. 1962, p. 204-211.

Experimental investigation of the characteristics of a 3, 2 line double-beam $N^{14}H_3$ maser, by using the Zeeman effect for the determination of the reference frequency. The shift of the reference frequency due to a variation of 30% in the ammonia pressure, 20% in the focuser voltage, or 10% in the intensity of the perturbing magnetic field is less than one part in 10^{10} . The variation in the traveling-wave effect by change of the effective beam intensity, both in single-beam and double-beam types, is calculated for practical use. The phase variation and noise in the frequency multiplier and the quartz oscillator are preliminarily investigated in order to improve the precision of frequency comparison between the maser and the quartz-crystal oscillator.

A63-12685

LARGEUR DE RAIE D'UN OSCILLATEUR LASER, CONSIDERE COMME LE SIEGE D'UNE REACTION EN CHAÎNE [THE LINE WIDTH OF A LASER OSCILLATOR CONSIDERED AS A SEAT OF A CHAIN REACTION]. Augustin Blaquièrre (Institut d'Electronique, Orsay (Seine-et-Oise), France).

Académie des Sciences (Paris), Comptes Rendus, vol. 255, no. 23, Dec. 5, 1962, p. 3141-3143. In French.

Calculation of the line width of a laser oscillator based on the formal analogy between the stimulated emission phenomenon and the fission phenomenon. The laser oscillator is considered to be a supercritical system stabilized by the nonlinear effects.

A63-12816

THRESHOLD RELATIONS AND DIFFRACTION LOSS FOR INJECTION LASERS.

G. J. Lasher (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.)

IBM Journal of Research and Development, vol. 7, Jan. 1963, p. 58-61.

Contract No. DA-36-039-sc-90711.

Derivation of formulas for the minimum current necessary to obtain coherent-light emission in terms of the dimensions of the resonant structure and measurable physical characteristics of injection-light sources. The structure considered is a rectangular, semiconducting crystal, with holes and electrons being injected into opposite faces. Within the crystal there is an active layer of thickness which emits light when a current is passed through the device. The threshold current density is found by equating the gain, due to stimulated emission with the sum of the losses caused by reabsorption or scattering by the crystal, transmission through the reflecting strips, and diffraction toward the sides of the crystal. As an example, the threshold current density for a gallium-arsenide crystal is calculated and found to be 830 amp/cm^2 . A new method of calculating the diffraction loss, which applies when the light-emitting layer is surrounded by light-absorbing material, is presented in an appendix.

A63-12846

IRON SAPPHIRE MASER WITH NO MAGNETIC FIELD.

G. E. Friedman and A. W. Nagy (Johns Hopkins University, Applied Physics Laboratory, Silver Spring, Md.)

IEEE, Proceedings, vol. 51, Feb. 1963, p. 361, 362.

Contract No. NOW 62-0604-c.

Description of observed maser action in trivalent iron-doped sapphire with no magnetic field. It is believed that this is the first reported microwave maser operation with only crystalline field splitting.

A63-12847

FOUR-LEVEL K_u -BAND MASER.

E. J. Schimitschek, E. G. K. Schwarz, and W. G. Turnbull (General Dynamics Corp., Astronautics Div., San Diego, Calif.) IEEE, Proceedings, vol. 51, Feb. 1963, p. 363, 364.

Description of the design and the observed performance characteristics of a four-level, push-pull maser using a reflection-type cavity. The device has been built and operated at 15.4 Gc. The simplicity of the coupling arrangement between the cavity and the two waveguides is noted. The capacitive tuning screw in front of the cavity provides for adjustable coupling. This arrangement makes it possible to attach an auxiliary cavity to the opposite wall of the signal guide which resonates at a slightly different frequency and can be used to increase the bandwidth of the device.

A63-13023

LASERS: PRINCIPLES AND USES.

Stuart A. Collins, Jr. (Sperry Rand Corp., Sperry Gyroscope Co., Great Neck, N. Y.)

Electro-Technology, vol. 71, Mar. 1963, p. 64-70. 32 refs.

Survey of the theory and applications of solid-state and gaseous lasers. The different types of energy levels in laser ions and atoms are discussed for a ruby laser, a calcium tungstate laser, and a helium-neon laser. Calculation of light intensity from a laser is demonstrated, as is a lens system for improving the collimation of a laser beam. Some laser applications are described for a ruby laser that radiates a 10-kw pulse in red light, and for a neon-helium laser that operates continuously on several frequencies at a power of 3 mw. Laser-device modifications based on the use of the laser Q switch, mode selectors, or spike control are noted.

A63-13105

A METHOD FOR EVALUATING LASER POTENTIALITIES OF CRYSTALS.

H. H. Theissing, P. J. Caplan, T. Ewanizky, and G. de Lhery (U.S. Army, Signal Research and Development Laboratory, Fort Monmouth, N. J.)

Applied Optics, vol. 2, Mar. 1963, p. 291-297.

Description of optical measurements of a laser figure of merit with reference to a particular pumping device in order to evaluate the laser potentialities of various crystals, or to compare one crystal with another of changed composition and concentration. It is pointed out that these measurements can be performed on slabs without laser end faces. They can be carried out by irradiation with white light in which the fluorescence wavelength under study is suppressed. If optical apparatus for this selective band suppression is not available, the evaluation of the figure of merit is shown for monochromatic irradiation.

A63-13106

SOME NEW ASPECTS FOR LASER COMMUNICATIONS.

Gerhard K. Megla (Hoffman Electronics Corp., Science Center Div., Santa Barbara, Calif.)

Applied Optics, vol. 2, Mar. 1963, p. 311-315.

Critical examination, in view of the dual nature of the electromagnetic waves, of the information rate that can be carried by an optical wave. Examples are given to illustrate the attainable information capacity over a wave range from 10^{-2} to $10^3 \mu$ for constant antenna gain and for constant diameter of the collimator. In addition, the reduction in information capacity due to the finite travel time of the electromagnetic energy in interstellar communication channels is analyzed.

A63-13107

MEASUREMENTS AND INTERPRETATION OF LASER BEAM DIVERGENCE.

V. Evtuhov and J. K. Neeland (Hughes Research Laboratories, Malibu, Calif.)

Applied Optics, vol. 2, Mar. 1963, p. 319, 320.

Measurements of the divergence of a laser beam radiated in a two-lobe pattern, indicating that the angle of divergence between the two maxima is not constant, close to the ruby. The predicted divergence of the pattern maxima is found to agree very well with that observed. This agreement is interpreted as a strong indication that the pattern constitutes a simple transverse oscillation mode. The intensity variation in the beam cross section 50 cm away from the ruby is calculated and graphically represented. The divergence angle of a somewhat more complicated pattern is also measured, and is found to be approximately 3.4 milliradians. This may explain the commonly observed increase in the divergence angle with pump power, since increased pump power implies excitation of more complicated patterns.

A63-13193**PROPOSAL FOR MASER WITH EMISSION FREQUENCY HIGHER THAN PUMPING FREQUENCY.**

M. Odehnal (Academy of Sciences, Institute of Nuclear Research, Prague, Czechoslovakia).

Czechoslovak Journal of Physics, Series B, vol. 13, no. 1, 1963, p. 8-13. 10 refs.

Description of a proposal for a maser which would provide an emission frequency somewhat higher than the pumping frequency. Basically, it is a combination of a three-level and a two-quantum maser. Four types of this maser in three- and four-level systems are analyzed, and the probability of a two-photon process is derived, using the perturbation theory. The application of this type of maser to electric dipole transitions in gases is discussed.

A63-13229**LES "LASERS."**

P. Ghendrih (Compagnie Générale de Télégraphie sans Fil, Paris, France).

Navigation (Paris), vol. 11, Jan. 1963, p. 23-31. 10 refs. In French.

Description of the principle of stimulated emission and the operation of various lasers, including ruby, gas, and trip types. Possible areas of application include space communications, navigation, and military uses. Also considered are applications to biology where lasers will be used to study the structure of cells; and to chemistry, where they will be utilized to study various chemical reactions and to analyze the phases taking place in the reactions.

A63-13595**QUASI-CONTINUOUS OUTPUT FROM A RUBY OPTICAL MASER.**

M. S. Lipsett and L. Mandel (University of London, Imperial College of Science and Technology, Dept. of Physics, London, England).

Nature, vol. 197, Feb. 9, 1963, p. 547, 548.

Description of observations of quasi-continuous output from a ruby optical maser oscillating with a nonuniform distribution of energy along the length of the maser rod. An explanation is offered of the quasi-continuous output. If this explanation is correct in principle, any configuration giving rise to modes with a nonuniform distribution of energy might be expected to reduce the tendency of maser crystals to exhibit spikes. It is noted that this point should not be too difficult to investigate, and that it might provide a clue to the design of ruby optical masers for producing continuous oscillations.

A63-13798**ULTRASONIC-REFRACTION SHUTTER FOR OPTICAL MASER OSCILLATORS.**

A. J. DeMaria, R. Gagosz, and G. Barnard (United Aircraft Corp., Research Laboratories, East Hartford, Conn.)

Journal of Applied Physics, vol. 34, Mar. 1963, p. 453-456.

Description of experiments that demonstrate an ultrasonic shutter suitable for obtaining giant pulses from a ruby optical maser by utilizing the refraction resulting from the passage of a plane-parallel light beam. Amplitude, rise time, and pulse duration are comparable with the values reported utilizing a Kerr cell, and superior to those reported for rotating mechanical shutters. In addition, the ultrasonic shutter can be utilized to synchronize the usually random output pulses of a ruby optical maser with the ultrasonic frequency.

A63-13799**POWER AND EFFICIENCY CONSIDERATIONS IN CONTINUOUS LASER OPERATION. Appendix - STEADY-STATE EQUATIONS FOR 4-LEVEL LASER.**

D. R. Frankl (General Telephone and Electronics Laboratories, Inc., Bayside, N. Y.)

Journal of Applied Physics, vol. 34, Mar. 1963, p. 459-462. 12 refs.

Summary of various factors entering into the continuous operation of optically pumped solid-state lasers. Numerical estimates for ruby and for Nd⁺⁺⁺-activated materials in two types of optical systems suggest that several watts of output power should, ideally, be obtainable when pumping with a 1-kw Hg arc lamp.

A63-13802**A CIRCULARLY POLARIZED MASER OSCILLATOR.**

Toru Ogawa (Massachusetts Institute of Technology, Research Laboratory of Electronics, Cambridge, Mass.)

Journal of Applied Physics, vol. 34, Mar. 1963, p. 484-489. 11 refs.

USAF-Army-Navy-sponsored research; Contract No. DA-36-039-sc-87376.

Observation of the frequency stability of a circularly polarized, solid-state, paramagnetic maser oscillator in order to obtain information needed to construct a frequency standard with a broad, microwave spectral line. By using ruby, the beat frequency between two such masers can be made almost free from the variation in the static magnetic field and the angle between it and the crystalline axes. The stability of the 1.5-Mc beat frequency is approximately 10^{-6} for short-time intervals, and is approximately 10^{-5} for long-time intervals. The short-time stability is limited mainly by the fluctuation of the cavity resonant frequency in the liquid helium. The long-time stability is determined by the drift of the pump frequency, although the reason for this interrelation is not thoroughly understood. The effect of reflections from the load on frequency is considerably reduced by the unidirectional structure used, as compared with that to be expected with a reflection type of maser. It is also shown that the unidirectional maser amplifier can be built with reduced cross section by utilizing a dielectric-loaded circular waveguide.

A63-13806**GASEOUS OPTICAL MASER WITH EXTERNAL MIRRORS.**

Thomas G. Polanyi and William R. Watson (General Telephone and Electronics Laboratories, Inc., Bayside, N. Y.)

Journal of Applied Physics, vol. 34, Mar. 1963, p. 553-560.

Description of radiation patterns obtained with He-Ne masers employing mirrors external to the discharge region. Operation was obtained with discharge tubes having Brewster angle windows, windows perpendicular to the optical axis, two spherical, one flat and one spherical, and two flat mirrors. Mode selection by using obstacles interposed in the cavity is described. It is shown that the radiation pattern is established within a very small region of the cavity. Comparisons of lasers operating with external and internal mirrors show that the lack of azimuthal symmetry of the radiation patterns is intrinsic to the spherical mirror geometry, and not to the Brewster angle windows.

A63-13810**IDENTIFICATION OF LASING ENERGY LEVELS BY SPECTROSCOPIC TECHNIQUES.**

E. J. Blau, B. F. Hochheimer, J. T. Massey, and A. G. Schulz (Johns Hopkins University, Applied Physics Laboratory, Silver Spring, Md.)

Journal of Applied Physics, vol. 34, Mar. 1963, p. 703.

Contract No. NOw 62-0604-c.

Investigation of a spectroscopic technique which may allow an assignment of the specific energy levels involved in lasing action in cases where spectroscopic resolution is a problem, or where there is a scarcity of data in certain spectral regions. This technique is applied to the He-Ne laser in order to determine which of the two neon lines ($2s_2$ to $2p_4$ at 11,522.8 Å or $2s_4$ to $2p_7$ at 11,525.1 Å using Paschen notation) is lasing. During the course of investigation, several new lasing lines in the IR are found in the region about 1.43 μ.

A63-13811

QUANTUM EFFICIENCY OF RUBY.

Gerald Burns and Marshall I. Nathan (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.)

Journal of Applied Physics, vol. 34, Mar. 1963, p. 1703-705.

Study of the quantum efficiency (η) of the red emission of Cr^{3+} in Al_2O_3 (ruby). It is shown that from 77°K to 240°C, the quantum efficiency is independent of temperature. The fraction of the radiation that is emitted in the R lines themselves (η_R) is measured. This is the quantity that decreases rapidly at high temperatures, but even at 77°K it is less than 0.6. The rest of the radiation in the region comes from the R line emission with phonon interaction. The relative quantum efficiency as a function of temperature is measured by exciting the ruby (0.05% Cr^{3+} crystals and a laser rod with slightly less Cr^{3+}) with light from a mercury arc filtered with 1 in. of a saturated solution of copper sulfate and a blue filter. Thus, no radiation with a wavelength longer than 6,000 Å is incident on the ruby.

A63-13812

RADIATION PATTERNS OF CONFOCAL HE-NE LASER.

W. R. Watson and Thomas G. Polanyi (General Telephone and Electronics Laboratories, Inc., Bayside, N. Y.)

Journal of Applied Physics, vol. 34, Mar. 1963, p. 708, 709.

Study of radiation patterns of a confocal He-Ne laser having mirrors inside the envelope of the discharge tube so that no windows are required in the cavity between the mirrors. At high levels of excitation, the radiation patterns of this internal laser are complex and can hardly be distinguished from those of a laser having Brewster angle windows within the cavity; the patterns are quite different, however, from those of lasers having perpendicular windows. On the basis of this examination, it is concluded that (1) the usual complicated appearance of radiation patterns of a confocal laser results from simultaneous oscillation in many modes; (2) the rectangular arrays found in lasers having Brewster angle windows are not produced by the windows but are, at most, selected from normal modes of the confocal cavity; (3) the higher degree of circular symmetry exhibited in patterns from external lasers having perpendicular windows in the cavity results from a strong selection against the more common rectangular modes of the cavity; and (4) confocal, in contrast to concentric, lasers give more complicated patterns simply because they support a larger number of modes simultaneously for a given gain per pass through the amplifying region of the tube.

A63-14131

SOME CHARACTERISTICS OF A GENERATOR (LASER) USING A MIXTURE OF HELIUM AND NEON.

N. G. Basov, E. P. Markin, and D. I. Mash (Academy of Sciences, P. N. Lebedev Physics Institute, Moscow, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 43, Sept. 1962, p. 1116, 1117.)

Soviet Physics - JETP, vol. 16, Mar. 1963, p. 788. Translation.

Experimental investigation of the change in generator power with degree of excitation, for various partial pressures of helium and neon. Generator power is found to remain practically unchanged when the partial pressures of helium and neon are increased from 1:10 to 1:4, but to decrease rapidly with further increase in partial pressure.

A63-14176

LIMITATIONS ON LASERS FOR DEEP-SPACE COMMUNICATION.

L. R. Bittman (Martin-Marietta Corp., Baltimore, Md.) (Institute of Electrical and Electronics Engineers, Winter General Meeting, New York, N. Y., Jan. 27-Feb. 1, 1963, Paper 63-57.)
Electrical Engineering, vol. 82, Mar. 1963, p. 220-223.

Comparison of conventional radio techniques with laser communication systems, in order to establish the possible extent of laser application in space. A brief analysis of the photon energy effect and the optimum antenna diameter shows that laser communication systems will probably not be employed in space as extensively as was initially supposed, even when highly coherent CW-operating and high-conversion-efficiency devices are developed. On the other hand, an examination of relative communication-system efficiency reveals that a laser operating in the 8- to 13- μ range of the IR region may provide the most efficient communication.

A63-14251

INFLUENCE DES CIRCUITS HYPERFREQUENCES SUR LES PERFORMANCES D'UN MASER A CAVITES COUPLEES [THE INFLUENCE OF UHF CIRCUITS ON THE PERFORMANCE OF A COUPLED-CAVITY MASER].

G. Broussaud and L. Malnar (Compagnie Générale de Télégraphie (International Scientific Radio Union (URSI), Symposium, Paris, France, Sept. 18-22, 1961.)

IN: Space Radio Communication. New York, Elsevier Publishing Co., 1962, p. 295-318. In French.

Study of some of the significant aspects of the behavior of coupled-cavity masers, with particular attention to the effects of UHF structures on the performance character. It is shown that such qualities as gain, band pass, and gain stability can be modified in order to influence the geometry of the UHF structure associated with maser materials.

A63-14304

LASER RANGING.

M. R. Klop (General Electric Co., Light Military Electronics Dept., Utica, N. Y.)

Space/Aeronautics, vol. 39, Apr. 1963, p. 89-92.

A detailed discussion of the characteristics of laser ranging systems, their optics, filter, and photomultiplier tube. Computation shows that for a range of 18 miles a target cross-section would be illuminated with a beamwidth of 0.5 millirad, a receiving aperture of 10 in.² giving a target reflectivity of 0.4 and a noise equivalent power of 9×10^{-6} . The present state-of-the-art indicates that lasers with a range of 400 miles are feasible.

A63-14392

NEW LIGHT ON ANGULAR STABILITY.

General Precision Aerospace, Technical News Bulletin, vol. 6, 1st Quarter, 1963, p. 4-9.

Discussion of a theory of an absolute angular reference which can be applied to an "optical gyroscope." The theory is based on laser research which suggests the existence of an optical nodal pattern, generated in a specially shaped laser, that has absolute angular stability in inertial space. The result of an initial investigation of how to best employ this theory, results in an arrangement related to the Sagnac effect for measuring absolute angular velocity. Experiments are conducted utilizing a straightforward Sagnac apparatus in a small instrument which uses visible light. Laser operation is briefly outlined, and an experimental arrangement for determining the difference frequency of two light sources - which is directly proportional to the angular velocity of the apparatus - is described.

A63-14407

HIGH-INDEX-OF-REFRACTION SPHERICAL SHEATH COMPOSITE-ROD OPTICAL MASERS.

O. Svelto and M. Di Domenico, Jr. (Stanford University, W. W. Hansen Laboratories of Physics, Microwave Laboratory, Stanford, Calif.)

Applied Optics, vol. 2, Apr. 1963, p. 431-439. 15 refs.
NSF Grant No. G-22929.

Theoretical and experimental investigation of the focusing of pumping light by high index-of-refraction spherical and cylindrical sheaths covering a ruby-rod maser material. The reduction in threshold pumping energy and the increase in optical output energy for the same ruby rod are measured as a function of the index of refraction of the sheath by using spherical and cylindrical sheaths of water and benzyl benzoate. Results clearly show that the spherical sheath is better than the cylindrical sheath. A thermodynamic method of analysis is used to develop an approximate three-dimensional theory for the power absorbed per unit volume at each point in the rod. This theory treats the spherical and cylindrical sheath composite-rod structures in a unified way. The theoretical results are in fair agreement with the experiment. The theory shows that the spherical sheath of sapphire is an optimum composite-rod optical-maser configuration. The theory predicts that in this case the threshold pumping energy for maser oscillation should be reduced by a factor of 4, whereas the cylindrical sheath of sapphire should give an improvement by a factor of only 2.4.

A63-14409**INTERFEROMETER LASER MODE SELECTOR.**

S. A. Collins and G. R. White (Sperry Rand Corp., Sperry Gyroscope Co., Great Neck, N. Y.)

Applied Optics, vol. 2, Apr. 1963, p. 448, 449.

Discussion of a new type of laser mode selector, composed of tilted Fabry-Perot etalons placed internal to the laser. The selector is unique in that it simultaneously performs two functions: it limits the frequency spectrum radiated, and it narrows the beam angle. Simple analysis is used to determine design parameters. Tests demonstrate the frequency rejection and beam narrowing expected. Single etalon mode selectors can be designed to give single frequency output and beam angle at the diffraction limit.

A63-14410**OPTICAL PUMPING OF LASERS USING EXPLODING WIRES.**

Charles H. Church, R. D. Haun, Jr., T. A. Osial, and E. V. Somers (Westinghouse Electric Corp., Westinghouse Research Laboratories, Pittsburgh, Pa.)

Applied Optics, vol. 2, Apr. 1963, p. 451, 452.

Description of several experiments on the optical pumping of lasers. It is found that the exploding wire allows much higher pumping rates than flash lamps. As a source of light, in the visible spectrum the wire appears to be less efficient. It is noted that the efficiency of the wire for pumping lasers could be enhanced appreciably by a better choice of laser conditions, together with improved coupling to the laser rod of the light emitted by the plasma.

A63-14633**OSCILLATION ON f-d TRANSITIONS IN NEON IN A GAS OPTICAL MASER.**

R. A. McFarlane, W. L. Faust, and C. K. N. Patel (Bell Telephone Laboratories, Inc., Murray Hill, N.J.)

IEEE, Proceedings, vol. 51, Mar. 1963, p. 468.

Presentation of the results of population inversion and laser oscillation measurements at wavelengths in the 1.8μ region on f-d transitions in neon not previously known to be inverted. The experimental technique is outlined. The new wavelengths at which oscillations are observed are indicated in a table. The results are briefly discussed, and compared with those of other investigators.

A63-14634**TOROIDAL RUBY LASERS.**

Dieter Röss (Siemens and Halske AG, Munich, West Germany).

IEEE, Proceedings, vol. 51, Mar. 1963, p. 468, 469.

Experimental investigation of a new structure - a resonant toroid of laser material with refractive index greater than 1, in which mode selection, cavity Q, and coupling in outward direction are rather independent, and can be controlled separately. The measurement of the tangential emission of two cylindrical toroids of ruby is described. It is seen that the outstanding property of toroidal lasers is the possibility of combining extremely high resonator Q with moderate selection leading to quasicontinuous oscillations in inhomogeneous material such as ruby.

A63-14773**THE INTERPLANETARY AND INTERSTELLAR COMMUNICATION POTENTIAL OF THE LASER.**

Donald S. Bayley.

General Precision Aerospace Technical News Bulletin, vol. 5, 4th Quarter, 1962, p. 12-17.

USAF-supported research.

Analysis of an idealized laser communication system in order to demonstrate its long-range communication potentials. The results of calculations for such a communication system are tabulated. On the basis of these data, it is concluded that the large communication potential of the optical frequency band will promote solution of the various problems involved in the alignment of the transmitter and receiver beamwidths and bandwidths. The use of a liquid as the active medium of the laser is briefly discussed. The results presented apply to an experiment for demonstrating the long distance communication potential of a ruby laser by using a diffusely reflecting Earth satellite as a highly attenuating link between Earth-based transmitting and receiving stations.

A63-15052**SPACE COMMUNICATIONS BY THE USE OF LASERS: AN ENUMERATIVE BIBLIOGRAPHY.**

Paul L. Simmons (North American Aviation, Inc., Space and Information Systems Div., Downey, Calif.)

IRE Transactions on Communications Systems, vol. CS-10, Dec. 1962, p. 449-456. 379 refs.

Bibliography on lasers, surveying the research and development which has been accomplished in their short history. Included are English, French, and Soviet articles published up to early 1962. A brief introduction to lasers is given.

A63-15272**FIELD-OPERATIONAL S-BAND MASER.**

Electronics, vol. 36, Mar. 29, 1963, p. 48.

Discussion of the development of an S-band traveling-wave maser in a closed-cycle liquid-helium refrigerator. The development establishes the feasibility of an ultra-low-noise solid-state receiver at remote antenna sites.

A63-16269**LASER Q-SPOILING USING AN EXPLODING FILM.**

J. I. Masters, J. Ward, and E. Hartouni (Technical Operations, Inc., Burlington, Mass.)

Review of Scientific Instruments, vol. 34, Apr. 1963, p. 365-367.

Discussion of Q-spoiling observed when an easily vaporized absorbing film located within the resonant structure of a ruby laser is destroyed by initial stimulated emission. It is shown that this new technique is operationally simple and has no severe power-handling limitations. The resulting laser output is characterized by a single giant pulse of microsec duration, the rise time of which (in the 20- to 40-nanosec range) is at least as long as that reported for Q-spoiling by Kerr-cell shutters.

A63-16400**RELAXATIONSSCHWINGUNGEN IN DER EMISSION OPTISCHER MASER MIT NEODYM IN CALCIUMWOLFRAMAT [RELAXATION OSCILLATIONS IN THE EMISSION OF OPTICAL MASERS USING NEODYMIUM IN CALCIUM TUNGSTATE].**

Karl Gürs (Technische Hochschule München, Fakultät der Allgemeinen Wissenschaften, Munich, West Germany).

Zeitschrift für Naturforschung, vol. 3, Mar. 1963, p. 418-420. In German.

Discussion of experiments with lasers using $\text{CaWO}_4:\text{Nd}^{3+}$ as the laser crystal. It is shown that the emission behavior of lasers can be numerically calculated, thus enabling the construction of lasers with desired emission characteristics. The experiments indicate that a simple emission behavior can be obtained only if the relaxation oscillations are damped oscillations. Oscillograms of the relaxation oscillations in the emission of the lasers under discussion are presented.

A63-16493

AEROSPACE, MILITARY LASER USES EXPLORED.
Barry Miller.

Aviation Week and Space Technology, vol. 78, Apr. 22, 1963, p. 54, 55, 61, 63, 64, 69.

Survey of the present and anticipated funding for development of the laser as a communications and detection device for military and astronomical use. Presented are tabulations and descriptions of government funded maser and related programs in 1963. The name of the contractor, the supporting agency, and the dollar value of each program are included.

A63-16530

A CRITIQUE OF RADAR IN SPACE.

Richard D. Taylor (Hughes Aircraft Co., Culver City, Calif.)
(Institute of Radio Engineers, National Symposium on Space Electronics and Telemetry, Miami Beach, Fla., Oct. 2-4, 1962.)

IN: PGSET Record of the 1962 National Symposium on Space Electronics and Telemetry. New York, Institute of Radio Engineers, Professional Group on Space Electronics and Telemetry, 1962. 20 p. (5.1).

Examination of various types of sensors in the light of their relative capabilities to satisfy mission requirements for space rendezvous, both cooperative and noncooperative. Conventional pulsed radar systems are selected as being, in general, the sensors best suited to the tasks. Various specific system configurations for the two types of missions at both long and short ranges are discussed, including functional block diagrams and major parameter lists. Consideration is given to the all-visual approach, and the advent of improved IR and optical laser systems is discussed in view of the advancing state-of-the-art.

A63-16626

LASERS FILL MEDICAL NEED.
Ed Addeo.

Electronics, vol. 36, Apr. 19, 1963, p. 30-32, 36.

Study of the practical application of lasers to the medical field, particularly ophthalmology. Possible uses discussed are: to close pinpoint holes that develop in the retina, to burn tumors, and other vascular diseases of the eye, and to cure many types of disorders of the iris. Reviewed are the design and application of an ophthalmoscope-laser, now under development.

A63-16636

OPTICAL RESEARCH AND THE SOLID STATE LASER.

J. M. Burch (National Physical Laboratory, Light Div., Teddington, Middlesex, England).

(Institute of Physics and Physical Society, Annual Exhibition, London, England, Jan. 15, 1963.)

Journal of Scientific Instruments, vol. 40, Apr. 1963, p. 147-152. 20 refs.

Review of recent progress in laser research. Emphasis is on the following areas: (1) examination of materials, both gaseous and solid, which have been used as the fluorescent devices and the improvements made on these materials; (2) application of lasers to communications and optical experiments; (3) theoretical considerations and comparisons of lasers with other light sources; and (4) factors which intervene to prevent the ideal single-mode type output of laser oscillators.

A63-16684

AN ANALYSIS OF RADIATION TRANSFER BY MEANS OF ELLIPTICAL CYLINDER REFLECTORS.

S. B. Schuldt and R. L. Aagard (Honeywell Research Center, Hopkins, Minn.)

Applied Optics, vol. 2, May 1963, p. 509-513. 10 refs.

Derivation of expressions which give the relative amount of pumping radiation transferred from a cylindrical source to a cylindrical laser by means of a reflector in the shape of an elliptical cylinder. The general expression depends upon the radii of the source and laser, the eccentricity of the ellipse and the length of its semimajor axis, and an arbitrary angular distribution of source radiation. The effect of radiation reflected back into the source

itself (source-blocking) is also considered. A considerable simplification in the calculation results when the source distribution is invariant under a rotation of the source about its axis - i. e., when the distribution depends only on the direction of the radiation with respect to the local normal, thus corresponding to virtually all practical cases. Moreover, the special case of a Lambertian source distribution yields efficiencies which may be evaluated directly. Especially simple and illustrative is the Lambertian source which is sufficiently small compared with the reflector so that source-blocking can be ignored.

A63-16777

OBSERVATION OF BEATS BETWEEN TRANSVERSE MODES IN RUBY LASERS.

C. M. Stickley (USAF, Cambridge Research Laboratories, Bedford, Mass.)

IEEE, Proceedings, vol. 51, May 1963, p. 848, 849.

Investigation of the simultaneous occurrence of different transverse modes in ruby lasers. The detection system used for the observation of beats between the transverse modes is illustrated. The obtained oscillograms indicate that the two beats occur in time coincidence with the spikes emitted by the ruby laser; the beat frequencies are within the range predicted by Schawlow and Townes. It is shown that the probability of observing the beats increases as the temperature is reduced.

A63-16778

MASER ACTION WITHOUT POPULATION INVERSION.

Dietrich Marcuse (Bell Telephone Laboratories, Inc., Holmdel, N. J.)

IEEE, Proceedings, vol. 51, May 1963, p. 849, 859.

Presentation of a specific example showing that the common assumption of the existence of a negative temperature (population inversion) being a prerequisite for any maser is not generally true. Utilizing the recoil frequency shift makes it possible, at least in principle, to achieve maser action with a material with no population inversion. It is only required that a sufficient number of atoms exist in the upper energy state.

A63-16780

OPERATION OF MASERS IN CLOSED-CYCLE HELIUM REFRIGERATORS.

W. H. Higa and E. Wiebe (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.)

IEEE, Proceedings, vol. 51, May 1963, p. 851, 852.

Contract No. NAS 7-100.

Discussion of test with a 960-Mc cavity-type maser in a closed-cycle refrigerator consisting of a compressor unit that supplies helium gas at 20 atm to a refrigerator unit. Tests in which the system was installed on an 85-ft-diam. paraboloid antenna, showed that the performance of the cavity maser was very satisfactory, and at least equivalent to its performance in ambient-pressure liquid-helium Dewars.

A63-16783

70-Gc MASER.

W. E. Hughes and C. R. Kremenek (Westinghouse Electric Corp., Air Arm Div., Applied Physics Group, Baltimore, Md.)

IEEE, Proceedings, vol. 51, May 1963, p. 856.

Army-supported research.

Investigation of a maser amplifier operated at a signal frequency of 70 Gc, with pump power supplied at a frequency of 118 Gc. The spin system used for operation is the iron ion Fe^{3+} in a host crystal of TiO_2 . It is shown that for such a millimeter-wave maser, it is possible to take advantage of slight differences in relaxation rates to obtain amplification at frequencies more than one-half the pump frequency. The advantage increases as the operating frequency increases, and can be of considerable interest to masers in the submillimeter region of the spectrum.

A63-16785

AFC OPTICAL HETERODYNE DETECTOR.

P. Rabinowitz, J. LaTourrette, and G. Gould (TRG, Inc., Syosset, N.Y.)

IEEE, Proceedings, vol. 51, May 1963, p. 857, 858.

USAF-supported research.

Discussion of experiments in which the FM output of one He-Ne (1.5μ) laser is detected by using a second He-Ne laser as the local oscillator in an optical heterodyne detector. By automatic frequency control of the second laser, a stable intermediate frequency of $10.7 \text{ Mc} \pm 3 \text{ kc}$ is generated. This makes it possible to use standard RF techniques for the modulation and detection of the FM signal.

A63-16786EFFECTS OF γ -IRRADIATION ON THE PERFORMANCE OF A RUBY LASER.

W. Flowers and J. Jenney (University of Michigan, Institute of Science and Technology, Ann Arbor, Mich.)

IEEE, Proceedings, vol. 51, May 1963, p. 858, 859.

Contract No. DA-36-039-78801.

Description of experiments showing that irradiation of ruby-laser rods with Co^{60} gamma rays substantially increases their efficiency. The increase in efficiency is seen to be caused by a more efficient absorption of the pump light by color centers produced in the ruby by irradiation. However, the mechanism of energy transfer between the color centers and the laser transition is not yet determined.

A63-16787

ATMOSPHERIC ATTENUATION OF RUBY LASERS.

Ronald K. Long (Ohio State University, Columbus, Ohio).

IEEE, Proceedings, vol. 51, May 1963, p. 859, 860.

Discussion of molecular absorption as it affects the propagation of ruby-laser emission in the atmosphere. Proceeding from the known phenomenon that the ruby-laser wavelength varies appreciably with temperature (from 6934 \AA at 88°K to 6943 \AA at 300°K), it is shown that atmospheric absorption can be avoided by temperature tuning the laser system.

A63-17399

RESOLUTION TEMPORELLE DE L'EMISSION LASER PAR PHOTOGRAPHIE ULTRA-RAPIDE EN DEFILEMENT CONTINU [TEMPORAL RESOLUTION OF LASER EMISSION BY CONTINUOUS HIGH-SPEED PHOTOGRAPHY].

Jean Ch. Viénot and Jean Bulabois (Lab. d'Optique Métrologique, Faculté des Sciences, Besançon, France).

Académie des Sciences (Paris), Comptes Rendus, vol. 256, no. 7, Feb. 11, 1963, p. 1475-1477. In French.

High-speed photographic study of interference phenomena in lasers. Such phenomena are seen to involve extremely intense, very short, elementary impulses followed by sequences of much longer duration of a marked periodicity. It is shown that the uncertainty relations greatly limit the experimental determination of the spectral profile.

A63-17681

ONSET OF STIMULATED EMISSION FROM GALLIUM ARSENIDE SEMICONDUCTOR OPTICAL MASERS.

R. F. Broom, C. H. Gooch, C. Hilsom and D. J. Oliver (Services Electronics Research Lab., Baldock, Hertfordshire, England).

Nature, vol. 198, Apr. 27, 1963, p. 368, 369.

Investigation of gallium arsenide junction diodes operated on a heat sink which is conduction-cooled with liquid nitrogen, so that the diode temperature is about 100°K . Light output as a function of position along the junction is discussed and shown graphically. It is

found that the spectral emission, as recorded by a spectrometer, varies markedly with the current density. An experiment at 90°K shows that as the temperature increases, the current required for maser action also increases. A partial hypothesis of the bright spots suggests that the current is not distributed uniformly over the area of the junction, and that the local current density is much higher than the mean current density.

A63-17865

NONLINEAR EFFECTS CONVERT LASER BEAM, AMPLIFY LIGHT. Warren Kornberg.

Electronics, vol. 36, May 3, 1963, p. 30-32.

Reports on the exploration of nonlinear optical effects on coherent light, of a method of energizing superconducting tape-wound magnets without high currents, and of a theoretical explanation of giant thermoelectric effects in dilute paramagnetic alloys. By proper selection of nonlinear optical materials, as calcite crystals, laser frequencies can be added or subtracted to obtain results anywhere in the visible spectrum. It is also suggested that parametric amplification is possible, by allowing, for example, laser light to pass through liquid nitrogen. The electromagnetic "energizer" eliminates the need for the large power supply needed to energize superconducting magnets using large currents. The explanation of the giant thermoelectric effects may lead to better control of thermoelectric devices.

A63-18060

TRANSMITTERS AND RECEIVERS FOR OPTICAL COMMUNICATIONS.

James R. McDermott.

Space/Aeronautics, vol. 39, June 1963, p. 98-106, 38 refs.

Discussion of optical transmitters using a CW helium-neon laser for microwave modulation of the beam, and an optical antenna as the beam-forming optics. Specifically examined are the principles of (1) an optical transmitter in which multichannel LF data are applied to a light beam by means of microwave modulation, (2) a microwave optical modulator system which uses an electro-optical microwave cavity and polarizers, (3) TRG's system (based on the piezoelectric principle) for tracking the local-oscillator laser frequency with the received-signal frequency, (4) General Telephone's optical transmitter-receiver system for TV-video signal transmission by microwave modulation of the laser beam. Noted are the use of the Pockels-effect microwave modulating cavity for microwave modulation, and the application of the superheterodyne principle to the reception of advanced types of modulation.

A63-18630

EVOLUTION OF THE GIANT PULSE IN A LASER.

William G. Wagner and Bela A. Lengyel (Hughes Research Laboratories, Malibu, Calif.).

Journal of Applied Physics, vol. 34, July 1963, p. 2040-2046.

The differential equations governing inversion and photon density in a laser are solved for giant pulse operation. The simplifying assumptions which permit solution involve homogeneous excitation of the laser and the neglecting of changes produced by pumping and fluorescence during the formation of the giant pulse. Energy, peak output power, pulse delay, and pulse width are calculated. The peak power output is found to be $10.5 \times 10^{16} \text{ watts/cm}^2$ of ruby.

A63-18810

NEW RESULTS ON THE RADIATION PROPERTIES OF OPTICAL MASERS (LASERS).

E. V. Shpol'skii.

Soviet Physics - Uspekhi, vol. 5, Jan.-Feb. 1963, p. 612-615. Translation.

[For abstract see Accession no. A63-10144 01-25]

A63-18854**LASER BEAM WELDING - HOW GOOD IS IT?**

Stephen M. MacNeille (American Optical Co., Southbridge, Mass.).
Tool and Manufacturing Engineer, vol. 50, June 1963, p. 59-63.

Discussion of the use of laser beams in welding technology. Described are laboratory tests in which recent progress in laser technology is successfully applied to produce spotweld joints on 0.005-in.-thick molybdenum and stainless-steel sheet. The spot size is a nominal 0.015 in., and the welds have excellent strength. The use of mathematical heat-transfer models to study the effect of thermal conduction on the conversion of optical energy into effective thermal work is noted.

A63-18864**MECHANISM OF SECOND HARMONIC GENERATION OF OPTICAL MASER BEAMS IN QUARTZ.**

Robert C. Miller (Bell Telephone Laboratories, Murray Hill, N.J.).
Physical Review, 2nd Series, vol. 131, July 1, 1963, p. 95-97.
10 refs.

Experimental determination and the interpretation of the relative magnitudes of the two independent coefficients, d_{11} and d_{14} , that appear in the tensor which describes the symmetry of second harmonic generation (SHG) of optical maser beams in quartz. Experimental data on these coefficients aid in determining the physical process involved in optical SHG. Data are obtained for both ruby ($6,934 \text{ \AA}$) and $\text{CaWO}_4:\text{Nd}^{3+}$ ($10,582 \text{ \AA}$) unfocused laser beams. These experiments, which failed to give any evidence of SHG due to d_{14} , show that $d_{14}/d_{11} < 1/30$ for the ruby laser, and $< 1/40$ for the Nd laser. The result $d_{14} \ll d_{11}$ shows that the mechanism involved in SHG in quartz is nearly lossless and dispersionless at the frequencies of the laser beams and their second harmonics. This further shows that in quartz the linear electro-optic effect and optical SHG cannot be due to the same mechanism. It is concluded that optical SHG in this material is due to an HF electronic mechanism.

A63-19689**CALCULATION OF THE MASER POWER OF A SYSTEM OF PARTICLES WITH THREE ENERGY LEVELS.**

B. I. Stepanov and A. M. Samson (Belorussian Academy of Sciences, Institute of Physics, Minsk, Belorussian SSR).

(Optika i Spektroskopiia, vol. 14, Jan. 1963, p. 65-72.)
Optics and Spectroscopy, vol. 14, Jan. 1963, p. 34-37. Translation.

Application of a probability method to calculate the maser power of a system of particles with three energy levels. The investigation is carried out for the following two possible cases of maser action: the generated energy corresponds to the transition of the system (1) from the middle to the lowest level, and (2) from the highest to the middle level. The conditions for the occurrence of intense generation are analyzed. The generated output is estimated as a function of the pump power and the transition probabilities. The radiation output power is compared with the fluorescence power.

A63-19829**SEMICONDUCTOR LASER.**

General Electric Company, Research Laboratory Bulletin, Summer 1963, p. 16, 17.

Discussion of a novel type of laser in which coherent light is generated directly by passing an electric current through a semiconductor crystal. The device does not require pumping by an auxiliary process; instead, the excitation is achieved directly by injecting electrons (and holes) into the plane of the junction region (a plane less than 0.0001 in. thick) in the middle of a tiny diode of gallium arsenide. The directional and coherent beam of IR light, with a wavelength of the order of 8400 \AA , is emitted from the junction-plane edges at two carefully polished and precisely parallel sides of the device.

A63-20064**COMPENSATION METHOD OF MEASURING THE EFFICIENCY OF A MASER BEAM.**

V. V. Grigor'iants and I. N. Oraevskii.
Radio Engineering and Electronic Physics, vol. 7, Dec. 1962, p. 1938-1940. Translation.

Description of a method of measuring maser efficiency, which eliminates errors generally caused by the ionization gage. The gage is used to establish the coincidence of pressures of the gas in the operating cavity and the gas entering the cavity, when the number of molecules reaching the cavity (from the source or through the cap), and scattered therein, is equal to the number of molecules traveling away from the cavity towards the evacuated space. Since the absolute value of the pressure is insignificant, the measurements are unaffected by the evacuating action of the ionization gage. The measurement error in this method, as determined from operations with an ammonia-beam maser, is 12%.

A63-20182**TIME-RESOLVED SPECTROSCOPY OF RUBY LASER EMISSIONS.**

S. L. Ridgway, G. L. Clark, and C. M. York (Space Technology Laboratories, Inc., Physical Research Division, Redondo Beach, Calif.).

Optical Society of America, Journal, vol. 53, June 1963, p. 700-703.

Application of an image-converter camera to the study of transient phenomena in the emission from ruby lasers. The time variations of Fabry-Perot interference fringes produced by the coherent light from a laser were recorded. They indicate that (1) the mode of oscillation of the ruby can change from one relaxation-oscillation burst of emission, or laser spike, to another; (2) a monotonic progression of wavelengths frequently takes place in a sequence of spikes; (3) the oscillation mode can switch within a single spike; and (4) several modes of oscillation can occur in a single spike simultaneously. The multiplicity of modes increases with the pumping power. The wavelength separation between the simultaneous modes is found to correspond closely to an integral difference in the number of half-wavelengths between the silvered end faces of the ruby.

A63-20307**ADVANCES IN OPTICAL MASERS.**

Arthur L. Schawlow (Stanford University, Dept. of Physics, Stanford, Calif.).

Scientific American, vol. 209, July 1963, p. 34-45.

General review of recent developments in laser research. A description of a typical early ruby laser is given to illustrate the atomic basis of laser action. Among the new developments discussed are semiconductor junction lasers, which promise efficiencies well above 10%, and possibly approaching 100%, compared to the 1% efficiency of optically pumped solid state lasers and gas-discharge lasers. Means of achieving high output power are discussed, including the use of a giant-pulse technique capable of delivering a 50 megawatt pulse lasting about 10 nanosec, and an addition to this technique which can produce a peak power output of about 500 million watts in a beam of cross section less than 1 cm. A good lens of focal length 1 cm could focus this beam to a 10^{-3} cm spot where the beam intensity would be 10^{15} w/cm . Laser beams currently in use can, when properly focused, weld, vaporize, or melt a small amount of any substance.

A63-20402**LASERS. I.**

Aubrey Harris.

Wireless World, vol. 69, Aug. 1963, p. 370-375. 10 refs.

General description of the basic operating principles and characteristics of different classes of lasers. Those discussed are doped-crystal, gas-discharge, semiconductor-junction, and liquid. A table lists their operating characteristics, including output frequency, spectral width, beamwidth, pumping requirements, and efficiencies. The active materials and output wavelengths of various types of lasers are also tabulated.

A63-20450**SPECTRAL OUTPUT AND SPIKING BEHAVIOR OF SOLID-STATE LASERS.**

C. L. Tang, H. Statz, and G. DeMars (Raytheon Co., Research Division, Waltham, Mass.).

Journal of Applied Physics, vol. 34, Aug. 1963, p. 2289-2295.

Theoretical investigation of the multimode oscillations of solid-state lasers. The spatial variation in the field intensity of the various modes produces nonuniform distributions in the inverted

population, and there is little tendency for these distributions to smooth out, because of spatial cross relaxation. Such nonuniform distributions could lead to simultaneous oscillation in many modes. Formulas which relate the number of unstable modes to the pump power and various other maser parameters are obtained. The results show that it is difficult to obtain single-mode operation in conventional masers at high pumping levels. Ways of avoiding a non-uniform distribution density and methods of achieving high-power single-mode operation in practice are discussed. The effect of slow spatial cross relaxation on the spiking behavior is also examined.

A63-20451**VISUAL OBSERVATION OF PIEZOELECTRIC MODES.**

A. J. DeMaria and G. Barnard (United Aircraft Corp., Research Laboratories, East Hartford, Conn.).

Journal of Applied Physics, vol. 34, Aug. 1963, p. 2296, 2297. 10 refs.

Experimental investigation of amplitude modulation of a laser beam by a quartz crystal. In addition, the piezoelectric modes of the crystal are traced by means of an X-Y plotter. It is found that the rotation of the index ellipsoid of crystalline quartz by excitation of its resonant piezoelectric modes (having wavelengths much larger than the light beam width) is sufficient to achieve a large percentage of modulation of a light beam. The piezoelectric resonant modes of the crystal can be probed by monitoring the variation of the percentage of light modulation as the light beam traverses the face of the crystal.

A63-20455**THEORY OF PULSE PROPAGATION IN A LASER AMPLIFIER.**

L. M. Frantz and J. S. Nodvik (Space Technology Laboratories, Inc., Redondo Beach, Calif.).

Journal of Applied Physics, vol. 34, Aug. 1963, p. 2346-2349.

Solution, in closed form, of the photon transport equations describing the growth of a pulse in a laser amplifier. The one-dimensional problem of a beam of monochromatic light incident on the surface of a medium with an inverted population is considered. The equations are solved for an arbitrary input pulse and an arbitrary initial distribution of inverted population. The solutions are discussed for the particular cases of a square pulse and a Lorentzian pulse, both with a uniform initial population inversion.

A63-20733**TRENDS IN SEMICONDUCTOR RESEARCH.**

John Bardeen (University of Illinois, Urbana, Ill.).

Electronic Industries, vol. 22, June 1963, p. C12, C13, C17.

Brief review of both past and present semiconductor research. The development of transistors, from the first production of single crystals of Ge and Si to the current devices, is outlined. Factors influencing innovation and invention are briefly discussed. The study of plasma effects in semiconductors is noted, as is the development of junction lasers.

A63-21055**ADVANCES IN LASERS.**

L. M. Vallesse (ITT Federal Laboratories, Nutley, N. J.).

(International Electronics Convention, 10th, Rome, Italy, June 1963.)

Semiconductor Products, vol. 6, Aug. 1963, p. 25-33. 23 refs.

Discussion of advances in laser devices and in laser system applications. The devices considered are oscillators, modulators, and detectors, and include semiconductor lasers; the applications discussed are those for communications and radar systems. Included is a summary of the principal wavelengths of the stimulated emission which has thus far been achieved, and the modes of operation for these emissions. Regarding radar applications, it is noted that pulse widths as narrow as 0.1 μ sec and peak powers as high as 15 Mw can be obtained, using Q switches of mechanical or electro-optic type.

A63-21057**A DIRECTORY OF LASER ORGANIZATIONS.**

Semiconductor Products, vol. 6, Aug. 1963, p. 48-50, 56-62.

Listing of approximately 150 organizations active in the laser field. These organizations are listed alphabetically within the following categories: (1) laser suppliers - firms that manufacture and supply lasers; (2) laser materials suppliers - firms that supply crystals, glasses, chemicals, and other materials suitable for laser action; (3) laser accessory equipment suppliers - companies that offer power supplies, modulators, demodulators, instruments, and optical and other accessories used in laser systems; (4) laser research and development groups - organizations that seek to perfect lasers as components in various systems and programs or investigate the use of lasers as tools of research and production.

A63-21062**INVESTIGATION OF LASER MODULATION BY MODIFYING THE INTERNAL REFLECTION BARRIER.**

Harold A. Daw (New Mexico State University, Dept. of Physics, University Park, N. M.).

Optical Society of America, Journal, vol. 53, Aug. 1963, p. 915-917.

Consideration of the problem of penetration through an internally reflecting barrier, in connection with the extraction of a laser beam from an internally reflecting cavity. A quantity $d \log T / d \log n$ which relates the fractional change of transmittance to the fractional change of refractive index is defined and shown to be large for large barrier spacing. It is suggested that this strong dependence of transmittance on the value of n may be used in studying and controlling laser beams.

A63-21069**ON THE INTEGRAL EQUATIONS OF LASER THEORY.**

Samuel P. Morgan (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

IEEE Transactions on Microwave Theory and Techniques, vol. MTT-11, May 1963, p. 191-193.

Mathematical consideration of a class of integral equations with complex symmetric kernels which occur in laser theory. It is pointed out that integral equations of this class do not have some of the properties of integral equations with Hermitian kernels. In particular, the usual extremal principle by which the eigenvalues of a Hermitian kernel may be estimated using the Rayleigh-Ritz procedure does not apply to integral equations with complex symmetric kernels. It is suggested that the use of variational techniques to calculate diffraction losses in laser interferometers leads to results of doubtful accuracy.

A63-21164**INVESTIGATION OF RUBY OPTICAL MASER CHARACTERISTICS USING MICROWAVE PHOTOTUBES.**

B. J. McMurtry (Stanford Electronics Laboratories, Stanford, Calif., and Sylvania Electric Products, Inc., Microwave Division, Mountain View, Calif.).

Applied Optics, vol. 2, Aug. 1963, p. 767-786. 26 refs.

USAF-Army-supported research.

Application of photoelectric mixing techniques to the study of a ruby laser. Following a brief theoretical analysis of laser oscillation frequencies, extensive experiments are described. These experiments permit conclusions concerning: (1) the behavior of the laser's spectral output as a function of pump power and temperature, (2) the validity of applying homogeneous interferometer mode analyses to the case of ruby, and (3) the effects of fluorescence line-shape and stimulated emission in determining oscillation frequencies. In addition, they provide extremely high-resolution measurements of the oscillation line-width.

A63-21165**OVERHAUSER AND JEFFRIES-ABRAGAM EFFECT IN A FOUR-LEVEL SYSTEM.**

Mohan Lal Narchal and W. A. Barker (St. Louis University, Dept. of Physics, St. Louis, Mo.).

Applied Optics, vol. 2, Aug. 1963, p. 787-792. 12 refs. USAF-supported research.

Application of the method of partial distributions to compute the normalized population distribution in an electron-nuclear coupled spin system in which $I = S = 1/2$. The expressions obtained are more general than those reported previously in that they include the effects of competitive relaxation and competitive radiative induced transition probabilities. It is clear that positive and negative enhancement may be obtained either by the Overhauser or the Jeffries-Abraham effect irrespective of the relative magnitudes of the nuclear Zeeman and hyperfine interaction energies. A small enhancement is not necessarily due to incomplete saturation, but may well be the result of compensating emission and absorption.

A63-21166

APPLICATION OF THE SENARMONT POLARISCOPE TO ANALYSIS OF OPTICAL MASER LIGHT.

David Hellerstein (Baird-Atomic, Inc., Cambridge, Mass.).

Applied Optics, vol. 2, Aug. 1963, p. 801-805.

USAF-supported research.

Description of a Sénarmont polariscope suitable for optical maser work. It employs an optically active wedge and an analyzing polarizer to map the azimuthal angle onto a linear field, indicating this angle by null positions on a photographic plate. It measures the azimuth of linearly polarized light over a range of 180° with an accuracy at present of $\pm 1.5^\circ$ and distinguishes between right- and left-circularly-polarized light. This device is compact and relatively inexpensive; it requires no auxiliary electronic apparatus.

A63-21167

HOLE-BURNING MODEL OF OSCILLATION OF RUBY LASER.

A. J. DeMaria and R. Gagosz (United Aircraft Corp., Research Laboratories, East Hartford, Conn.).

Applied Optics, vol. 2, Aug. 1963, p. 807-810. 12 refs.

Application of a Space Technology Laboratories high-speed image-converter camera to study the time variation of the output radiation from a 15-cm-long ruby laser, the latter being operated with detached external reflectors separated by 61 cm. These data offer additional support for the "hole-burning" model type of oscillation for ruby lasers. Included are photographs of the simultaneous oscillation during one pulse of a ruby laser at two optical frequencies corresponding to the eigenwavelength of the Fabry-Perot cavity.

A63-21168

INTERFERENCE RINGS IN RUBY MASER BEAMS.

B. P. Stoicheff and A. Szabo (National Research Council, Ottawa, Canada).

Applied Optics, vol. 2, Aug. 1963, p. 811-815. 14 refs.

Presentation of the results of observations of the near-field ring patterns obtained with several different rubies at various distances from the rubies. Other experiments bearing on the origin of these ring patterns are also described. In addition, an interpretation of the ring pattern based on a simple optical model is given which appears to be in agreement with our experimental observations. These fringes arise from the interference of "off-axis" rays produced by scattering of light in the axial modes at the axial modes at the surfaces or within the ruby rod.

A63-21169

TILTED-PLATE INTERFEROMETRY WITH LARGE PLATE SEPARATIONS.

H. W. Moos, G. F. Imbusch, L. F. Mollenauer, and A. L. Schawlow (Stanford University, Stanford, Calif.).

Applied Optics, vol. 2, Aug. 1963, p. 817-822. 11 refs.

USAF-Army-supported research.

Derivation of multiple-beam interference fringes between nearly parallel surfaces at large separations, using very highly collimated monochromatic light sources. Sharp fringes displaying the surface contours are observed with separations as large as 20 cm. The requirements and limitations of the device are described, as well as some possible applications.

A63-21171

A NEW CONDENSER FOR A SUN-POWERED CONTINUOUS LASER.

P. H. Keck, J. J. Redmann, C. E. White, and R. E. DeKinder, Jr. (Texas Instruments, Inc., Dallas, Tex.).

(Optical Society of America, Fall Meeting, Rochester, N. Y., Oct. 3-5, 1962.)

Applied Optics, vol. 2, Aug. 1963, p. 827-831.

Description of a new optical condenser to concentrate sunlight effectively from a parabolic collector into a laser rod. The condenser has a conical part made of material of high refractive index with a field lens on the wider end of the cone, which faces the parabolic collector. Radiant flux concentrated into the narrow end of the cone is transferred into a small solid integrating sphere with highly reflecting walls. The laser rod is embedded in the sphere and is pumped from all sides by radiation reflected from the walls. Photometric data and performance characteristics of this condenser used with an arc-lamp source are presented. A Sun-powered system is proposed and compared to the arc-lamp system.

A63-21172

PERFORMANCE OF A CONTINUOUS-WAVE NEODYMIUM LASER.

P. H. Keck, J. J. Redmann, C. E. White, and D. E. Bowen (Texas Instruments, Inc., Dallas, Tex.).

(Optical Society of America, Fall Meeting, Rochester, N. Y., Oct. 3-5, 1962.)

Applied Optics, vol. 2, Aug. 1963, p. 833-837.

USAF-supported research.

Description of experiments with a continuous neodymium-doped calcium tungstate laser, operated at room temperature, using water cooling. A high-pressure compact xenon arc lamp with an ellipsoidal collector of 61-cm diameter and an opening of $f/0.4$ is used as a pumping source. The flux available from this source is concentrated into the $2 \times 2 \times 12$ mm laser rods of neodymium-doped calcium tungstate by either a straight cone condenser or by a chisel-shaped condenser. Both condenser designs are discussed. Continuous laser action is achieved for periods up to more than one hour, using water cooling at room temperature.

A63-21174

ANALYSIS OF STIMULATED RAMAN SCATTERING OF A GIANT LASER PULSE.

R. W. Hellwarth (Hughes Research Laboratories, Malibu, Calif.).

Applied Optics, vol. 2, Aug. 1963, p. 847-853.

Study of a simple form of simulated Raman scattering observed from a number of organic liquids which are placed in a Fabry-Perot optical cavity excited by a giant optical laser pulse from ruby. It is shown that when a Raman active material is placed inside the optical Fabry-Perot cavity resonator of a giant pulse laser, the high-power laser light pulse induces gain in the Raman material at frequencies shifted from the giant pulse frequency by Raman frequencies. If this gain is large enough to overcome cavity losses, a strong buildup of coherent light at the shifted frequency may ensue. The process is analogous to simulated fluorescence and is an example of simulated Raman scattering. The Raman output power is calculated as a function of time and its spectral content when the Raman material is in the laser cavity. From the resulting expressions the properties of the light generated by nitrobenzene inside a giant pulse ruby laser are calculated, and it is found that the results agree with observations made on that system.

A63-21175

OPTICAL QUALITY AND RADIATION PATTERNS OF RUBY LASERS.

C. Martin Stickley (USAF, Cambridge Research Laboratories, L. G. Hanscom Field, Bedford, Mass.).

Applied Optics, vol. 2, Aug. 1963, p. 855-860. 16 refs.

Comparison of near- and far-field radiation patterns for two different ruby laser crystals of known differing optical quality. It is shown that ring-width in far-field patterns is directly related to optical quality as measured using a Twyman-Green interferometer. Near-field patterns of the higher quality crystal ($\lambda/10$) that were observed using high-speed photographic equipment always appeared to be transverse modes of a cylindrical resonator whereas this was not true for the poorer-quality crystal ($\lambda/4$). An approximate mode

sequence during firing of the $\lambda/10$ laser rod shows a reproducible mode development (in time). A sudden switching to higher-order modes was observed, and several factors are suggested which could explain this.

A63-21176
INFLUENCE OF MAGNETIC FIELDS UPON GAS DISCHARGE LASERS.

Rudolf G. Buser, J. Kainz, and J. Sullivan (U. S. Army, Electronics Research and Development Laboratory, Fort Monmouth, N. J.).

Applied Optics, vol. 2, Aug. 1963, p. 861, 862.

Brief description of some experiments conducted to study the influence of a magnetic field upon the light output of a gas laser. A Perkin-Elmer Spectra-Physics gas-phase laser which provides a linearly polarized light beam at 6328 Å, 11523 Å, and 33912 Å is used in the measurements. The relative laser intensity as a function of a longitudinal magnetic field and the dependence of this effect on the polarity of the magnetic field are graphically illustrated.

A63-21177
ANALYSIS OF TRANSIENTS AND STABILITY IN AN IDEALIZED TWO-LEVEL LASER SYSTEM.

J. E. Ludman (USAF, Cambridge Research Laboratories, Bedford, Mass.).

Applied Optics, vol. 2, Aug. 1963, p. 862, 863.

Presentation of a relatively simple analytical solution to an idealized two-level laser system. Such a two-level system bears resemblance to the diode laser system. It is shown that this two-level laser would achieve a steady-state operation with constant pump rate. After a momentary disturbance of the steady state by some means, such as injection of a light pulse or addition of a pulse to the pump, the laser would return to its steady-state operation with a damped oscillation transient. The same transient is expected when the laser pump is first turned on.

A63-21179
SPHERICAL-MIRROR OSCILLATING INTERFEROMETER.

Donald R. Herriott (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Applied Optics, vol. 2, Aug. 1963, p. 865, 866.

Brief description of a high-Q, multiple-pass, spherical-mirror interferometer with one mirror oscillating in axial position to scan wavelength. The instrument is designed for the measurement of spectral characteristics of continuous optical masers. It has been used to obtain direct scans of distortion of energy in the separate modes of oscillation of a gaseous He-Ne maser. A diagram of the interferometer is included.

A63-21180
FAR-FIELD FABRY-PEROT DIFFRACTION PATTERNS OF A NEODYMIUM IN GLASS LASER.

C. Martin Stickley and Rudolph A. Bradbury (USAF, Cambridge Research Laboratories, Optical Physics Laboratory, Bedford, Mass.).

Applied Optics, vol. 2, Aug. 1963, p. 867, 868.

Observation of a Fabry-Perot ring structure emitted by a Nd glass laser rod similar to the ring-type radiation patterns generated by ruby lasers. It is believed that this structure is due to Fraunhofer diffraction for which the total diameter of the laser rod is the aperture. Photographs showing far-field radiation patterns 0.5 and 10% over threshold are included.

A63-21181
POWER DIP AT LINE CENTER OF GASEOUS LASERS.

S. Winsberg (TRG, Inc., Syosset, N. Y.).

Applied Optics, vol. 2, Aug. 1963, p. 868, 869.

Presentation of the results of an analysis of a dip occurring in the power output from gaseous lasers as the oscillating frequency is scanned over the Doppler line. The analysis is based on the rate equations for the population and fields. It is shown that when the field is oscillating at a specific frequency, two groups of atoms will respond, each possessing a Doppler-shifted central frequency equal to the applied frequency. When the applied frequency equals the central frequency atom, the two groups coalesce, and, depending on the ratio of the natural width to the Doppler width, the power output decreases.

A63-21337
EXTENSION OF THE LASER-PUMPED RUBY MASER TO MILLIMETER WAVELENGTHS.

D. P. Devor (Hughes Research Laboratories, Malibu, Calif.). (Institute of Electrical Engineers, Millimeter and Submillimeter Conference, Orlando, Fla., Jan. 7-10, 1963.)

IEEE Transactions on Microwave Theory and Techniques, vol. MTT-11, July 1963, p. 251-254. 15 refs.

Brief description of the operation of a microwave ruby maser in which the pump signal is the optical emission of a ruby laser. It is shown that, for operation in the millimeter spectrum, the application of a magnetic field of inordinately high intensity can produce Zeeman splitting of the Cr^{3+} levels at millimeter wave energy in the ground state in ruby. To obtain population inversion by optical pumping on the levels requires that the ratio of maser frequency to temperature be $\nu_{ij}/T \ll 14.4 \text{ Gc/sec } ^\circ\text{K}$. A broadening of the laser emission has been observed at increased power so that the limit on useful laser power can be given in terms of the absorption-line width of the maser optical pumping transition. Treating these various effects conservatively indicates that the laser-pumped ruby maser can be operated over the entire millimeter spectrum. The design of an apparatus with a hard superconductor electromagnet producing the field intensity required to accomplish this objective is given.

A63-21457
APPLICATIONS OF OPTICAL "MASERS" TO SPACE RESEARCH [APPLICAZIONI DEI "MASER" OTTICI ALLE RICERCHE SPAZIALI].

Giorgio Fiocco (Massachusetts Institute of Technology, Dept. of Electrical Engineering and Research Laboratory of Electronics, Cambridge, Mass.).

(International Communications Congress, 10th, Genoa, Italy, Oct. 7-12, 1962.)

Missili, vol. 5, Apr. 1963, p. 73-78. In Italian.

Consideration of the characteristics and some applications of optical masers in radar devices suitable for astronomical and geophysical research. Included is a simplified chart of the various equipment used to obtain optical echoes from the Moon surface. Experiments conducted to receive echoes from the Moon are described.

A63-21484
THE OPTICAL HETERODYNE: KEY TO ADVANCED SPACE SIGNALING.

Stephen Jacobs (TRG, Inc., Syosset, N. Y.).

Electronics, vol. 36, July 12, 1963, p. 29-31.

USAF-supported research.

Description of a method of using optical heterodyning with a laser system, for communications purposes. When information is carried on a monochromatic beam of light, optical heterodyning makes it possible to filter out and amplify only the bandwidth of interest - i.e., the information bandwidth. In addition to this advantage, a laser communications link has extremely narrow bandwidth, as contrasted with an RF system. It is noted that one feasible application of the optical heterodyne is extremely long-range, broadband communications through space.

A63-21808
SPECTRAL CHARACTERISTICS OF GaAs LASERS OPERATING IN "FABRY-PEROT" MODES.

P. P. Sorokin, J. D. Axe, and J. R. Lankard (IBM Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.). Journal of Applied Physics, vol. 34, Sept. 1963, p. 2553-2556. Army-supported research.

Presentation of high resolution measurements of the spectral output of GaAs injection lasers. The laser units studied were designed to work as Fabry-Perot oscillators. It is found that the main features can be understood in terms of conventional line-narrowing theories. Additional oscillations have been observed in modes other than the lowest-loss ones.

A63-21811

APPROXIMATE ELECTROMAGNETIC TRANSITION PROBABILITIES AND RELATIVE ELECTRON EXCITATION CROSS SECTIONS FOR RARE-GAS MASERS.

H. Stutz, C. L. Tang (Raytheon Co., Research Division, Waltham, Mass.), and G. F. Koster (Massachusetts Institute of Technology, Dept. of Physics, Cambridge, Mass.).

Journal of Applied Physics, vol. 34, Sept. 1963, p. 2625-2632. 14 refs.

Calculation of numerical values for the electromagnetic transition probabilities for a large number of rare-gas maser lines. The values are tabulated for assisting in the evaluation of existing and new gaseous masers, as well as for other applications such as work in astrophysics. In addition, in order to determine the dominant pumping mechanisms in such masers, an approximate method has been developed for calculating the relative cross sections under electron impact for production of various excited states from the ground state of the rare-gas atoms. A brief discussion of the experimental observations in the rare-gas masers is made in terms of the results given.

A63-21890

SEMICONDUCTOR QUANTUM GENERATOR USING GaAs P-N JUNCTIONS [POLUPROVODNIKOVYI KVANTOVYI GENERATOR NA P-N PEREKHODAKH V GaAs].

V. S. Bagaev, N. G. Basov, B. M. Vul, B. D. Kopylovskii, O. N. Krokhin, E. P. Markin, Iu. M. Popov, A. N. Khvoshchev, and A. P. Shotov (Lebedev Physics Institute, Moscow, USSR). Akademiia Nauk SSSR, Doklady, vol. 150, May 11, 1963, p. 275-278. In Russian.

Discussion of the generation of coherent light by means of GaAs p-n junctions at 77°K. The injection of minority carriers through a p-n junction was accomplished by direct pulsing at a pulse duration of 3 μ sec and a pulse period of 50 cycles. Presented are diagrams showing (1) the radiation intensity as a function of current density, and (2) the radiation spectrum for different current values. A photograph illustrates the luminosity region of the maser p-n junctions for various injection currents.

A63-22060

TIME-CORRELATED VARIATION IN THE SPECTRAL COMPOSITION OF THE RADIATION FROM THE RUBY LASER.

M. P. Vanjukov, V. I. Isaenko, and V. V. Liubimov. (Optika i Spektroskopiia, vol. 14, May 1963.)

Optics and Spectroscopy, vol. 14, May 1963, p. 389, 390. Translation.

Experimental study of ruby laser emission in order to determine how the spectral composition of the radiation varies with time. The spectral resolution was obtained with a Fabry-Perot interferometer, and an electron optical converter was used for the time scan. It is found that each of the spikes constituting the generated flash may consist of one, two, or three lines, and the wavelength of the light may vary by about 0.2 Å between different spikes.

A63-22069

COHERENCE TIME MEASUREMENTS OF LIGHT FROM RUBY OPTICAL MASERS.

Morley S. Lipssett and L. Mandel (Imperial College of Science and Technology, Dept. of Physics, London, England). Nature, vol. 199, Aug. 10, 1963, p. 553-555. 23 refs.

Experimental determination of the coherence time of the light pulses emitted by a ruby laser. The beat notes in the photoelectric fluctuations resulting from the superposition of light beams from

two independent ruby lasers on a photocell are detected. Analysis of oscilloscope traces of the superposed beams indicates a coherence time of the order of 0.5 μ sec.

A63-22282

THE EFFECT OF TEMPERATURE ON THE PROPERTIES OF GaAs LASER.

G. Burns, F. H. Dill, Jr., and M. I. Nathan (IBM Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.). IEEE, Proceedings, vol. 51, June 1963, p. 947, 948. 14 refs.

Consideration of the effect of temperature on the Fabry-Perot modes, threshold current density, and CW operation. It is noted that, in the GaAs injection laser, only moderate resolution equipment is needed to study the Fabry-Perot modes. The results of the modes at low temperatures are different than the line shapes obtained from diodes that have four optically flat sides. The measurement of the temperature dependence of the threshold current density for laser action shows that, in a particular type of structure, there is a well-defined threshold for stimulated emission determined by the current at which a sharp spike comes out of the broad spontaneous emission spectral line.

A63-22283

DUAL-CAVITY MASER USED IN MARS RADAR EXPERIMENT.

W. H. Higa and R. C. Claus (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.).

IEEE, Proceedings, vol. 51, June 1963, p. 948, 949. Contract No. NAS 7-100.

Discussion of the planetary radar experimental use of a dual-cavity ruby maser operating at 2,388 Mc installed on an 85-ft-diam. paraboloidal antenna. It is indicated that the principal advantage of the multiple-cavity maser is the improved gain stability over a single-cavity unit operating with the same total gain. A cross-sectional view of one of the two identical stages employed is shown. Liquid helium was kept out of the structure for added stability, and cryogenic fluids were replenished daily.

A63-22285

METHOD FOR DETECTING MICROWAVE MODULATED LIGHT.

G. H. Thiess (Texas Instruments, Inc., Information Systems Dept., Dallas, Tex.).

IEEE, Proceedings, vol. 51, June 1963, p. 950. Contract No. DA-36-039-SC-89221.

Description of an experimental arrangement for the detection of microwave-modulated light. Optical heterodyning is used to detect microwave-modulated light, employing relatively slow photodetectors. In order to obviate the peculiarity of lasers to "lase" simultaneously at several different optical frequencies, only one laser is used and the alignment is "built-in" when two axial modes of a single laser are used as if they were two lasers. If a continuous gas laser is available as a "light" source, a simple and convenient method of detecting microwave modulation of the light beam exists, using relatively slow and inexpensive photodetectors. It is noted that the primary usefulness of the method may be its convenience for testing microwave-light modulators in the laboratory.

A63-22383

OPTIMIZATION OF THE PARAMETERS OF MULTI-ELLIPTICAL LASER HEAD CONFIGURATIONS.

J. A. Ackerman (Aircraft Armaments, Inc., Cockeysville, Md.). IEEE, Proceedings, vol. 51, July 1963, p. 1032, 1033.

Analysis of the "imaging" characteristics of an elliptic cylinder. The efficiency of many small surface increments for the transfer of energy is examined, and a total efficiency figure is obtained by summing these incremental efficiency factors over the entire surface under consideration. The results, which do not take into account the radiation that goes directly from the source to the receiver, show that the direct radiation is inversely proportional to the distance between the source and receiver.

A63-22384**SOME EXPERIMENTS ON PARALLEL GAS LASERS WITHIN A COMMON OPTICAL CAVITY.**

R. A. Paananen and A. Adams, Jr. (Raytheon Co., Research Division, Waltham, Mass.).

IEEE, Proceedings, vol. 51, July 1963, p. 1036, 1037.

Demonstration of simultaneous laser action in a set of 14 parallel open-ended discharge tubes arranged in a circle on the inner periphery of a large support tube, the whole being bounded at the ends by two plane-parallel mirrors. The seemingly universal gain rule shows that the gain will fall to nonlaserable values for large tubes, unless perhaps it is compensated for by unusual laser lengths. It is noted that plasma instabilities become difficult to control in large unobstructed tubes at the gas pressures found useful in lasers. The problem consists of choosing a suitable subdivision of the available cross section into parallel channels, and exciting the same.

A63-22385**A NO-FIELD POWDER MASER.**

A. W. Nagy and G. E. Friedman (Johns Hopkins University, Applied Physics Laboratory, Silver Spring, Md.).

IEEE, Proceedings, vol. 51, July 1963, p. 1037.

Contract No. N0w-0604-c.

Demonstration of the feasibility of masering a powder with no magnetic field. Shown are the variations in the inverted signal transition with change in coupling to the sample. They indicate potentially usable gain-bandwidth for this mode of operation. It is noted that a no-field powder maser would be limited to operation around the zero-field splitting frequency. However, other suitable zero-field materials with splittings in the higher microwave ranges which have been tabulated offer a choice for possible fixed-frequency applications.

A63-22386**MICROWAVE MASER ACTION IN RUBY AT 78°K BY LASER PUMPING.**

A. Szabo (National Research Council, Radio and Electrical Engineering Division, Ottawa, Ontario, Canada).

IEEE, Proceedings, vol. 51, July 1963, p. 1037, 1038.

Description of the achievement of microwave maser action in ruby at liquid-nitrogen temperatures, using a ruby laser as a pump, and of measurements of the thermal tuning rate of the R_1 lines in ruby, using paramagnetic resonance in the ground state for detection of the laser output. Shown are the results of a thermal tuning experiment using the $2 \leftrightarrow 3$ electron-spin-resonance transition (levels numbered in order of increasing energy) for detection of the laser output. For the maser experiments, the temperature obtained, which represents the noise temperature of the maser amplifier under appropriate cavity conditions, indicates the low-noise high-temperature operation of microwave masers possible when using optical pumping.

A63-22496**MASERS FOR THE TELSTAR SATELLITE COMMUNICATIONS EXPERIMENT.**

W. J. Tabor and J. T. Sibilia.

Bell System Technical Journal, vol. 42, pt. 3, July 1963, p. 1863-1886.

Discussion of the design and characteristics of ruby traveling-wave masers operating at 4 Gc. These masers, characterized by an average gain of ≈ 35 db over a bandwidth of 25 Mc, are equipped with waveguide input transmission lines, rather than the previously employed coaxial cables. This change results in an overall noise temperature of 3.5°K for these devices, rather than the 10°K exhibited by earlier masers. The maser noise temperature now closely approximates sky temperatures, which set the ultimate limit on Earthbound receiver sensitivity. The improvements to be gained by further reduction in amplifier noise are therefore almost negligible. A lesser-known maser property (freedom from distortion, even when driven well into gain saturation) is discussed.

A63-22790**OPEN RESONATORS FOR LASERS.**

L. A. Vainshtein (Vavilov Institute of Physical Problems, Moscow, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 44, March 1963, p. 1050-1067.)

Soviet Physics - JETP, vol. 17, Sept. 1963, p. 709-719. 17 refs. Translation.

Development of a theory of natural vibrations for resonators consisting of sections of circular or plane waveguide or formed by plane parallel mirrors of rectangular or circular shape. This theory is based on a rigorous theory of the diffraction at the open end of a waveguide and leads to simple and graphic relations whose accuracy increases with the increase of the frequency and with the decrease of the radiative damping of the oscillations. Resonators of these types are of interest for lasers, and also for the physics and technology of millimeter and submillimeter waves.

A63-22997**OPTICAL MASERS.**

J. R. Singer (University of California, Dept. of Electrical Engineering, Berkeley, Calif.).

IN: Cryogenic Technology. Edited by Robert W. Vance. New York, John Wiley and Sons, Inc., 1963, p. 311-331. 114 refs.

Discussion of the optical or electronic excitation of gases and solids, and of the consequent coherent emission in the submillimeter, IR, or optical frequencies. Some ideas of Schawlow and Townes on general design principles of IR and optical coherent oscillators and amplifiers are reviewed. The problem of constructing a resonant structure with dimensions equal to one, or even a few, wavelengths, is considered, together with specific systems for obtaining inverted level populations. Also described is the possibility of obtaining negative absorption (amplification) by examining the relative populations of the upper- and lower-level states of atomic hydrogen in a Wood's electrical discharge tube.

A63-23016**COHERENT GENERATORS OF OPTIC RANGE [KOGERENTNYE GENERATORY OPTICHESKOGO DIAPAZONA].**

A. L. Mikaelian and Iu. G. Turkov.

Radiotekhnika i Elektronika, vol. 8, May 1963, p. 731-758. 88 refs. In Russian.

Review of the present state of research activities in the field of lasers. The principles of operation of both solid-state and gaseous lasers are considered. Different designs of lasers are described and their parameters given.

A63-23328**INTERNAL NOISE AND SIGNAL-TO-NOISE RATIO OF A TUNED LASER AMPLIFIER.**

Donald S. Bayley (General Precision, Inc., GPL Division, Aerospace Group, Pleasantville, N. Y.).

Institute of Electrical and Electronics Engineers, International Conference and Exhibit on Aerospace Support, Washington, D. C., Aug. 4-9, 1963.

IEEE Transactions on Aerospace, vol. AS-1, Aug. 1963, p. 1111-1114.

Demonstration that, for signals received from a laser transmitter, a low level of internal noise could be achieved in a tuned laser amplifier. The requirements on bandwidth and beamwidth for such an amplifier are discussed.

A63-23544**COHERENT LIGHT.**

C. Chapin Cutler.

International Science and Technology, Sept. 1963, p. 54-58, 60, 62, 63.

Discussion of the effect of coherence on the behavior of light. Coherence can mean that waves are in phase either in the direction of propagation or in a plane perpendicular to the direction of propagation; both are necessary for complete coherence. The degree of

coherence in laser beams is discussed. Because of their coherence, laser beams can be focused into an intense spot or radiated in narrow beams having unequaled signal-carrying capacity. A less familiar consequence of coherence is the appearance of the light when it is scattered off a surface. The waves interfere to make the surface appear to be covered with a multitude of scintillating spots. The effect may have novel applications.

A63-23678**THE PERFORMANCE OF AN AMMONIA MASER WITH TWO RESONATORS IN CASCADE.**

D. C. Lainé and R. C. Srivastava (North Staffordshire University College, Dept. of Physics, Keele, Staffordshire, England). (British Institution of Radio Engineers, Masers and Lasers Symposium, London, England, Jan. 2, 1963.) Radio and Electronic Engineer, vol. 26, Aug. 1963, p. 173-180. 14 refs.

Description of an ammonia maser in which an additional resonant structure is inserted between the microwave cavity and the electrostatic separator. Observation of the power level of the microwave oscillation is shown to be a sensitive means of detecting various types of molecular transition in the auxiliary resonator. It is found that when this auxiliary resonator is a microwave cavity which can be tuned across the molecular resonance, the power level of the oscillation in the maser cavity varies in a more complex way than would be expected on consideration of population differences alone. The case when the auxiliary cavity takes the form of a multimode ultramicrowave resonator is also considered. It is suggested that transitions of ammonia molecules among the various rotational levels should be observable through changes in the amplitude of microwave oscillation.

A63-23809**MICROWAVE INVERSION EFFICIENCY OF ORANGE RUBY.**

D. G. Jolley and S. D. McLaughlan (Royal Radar Establishment, Malvern, Worcestershire, England). Nature, vol. 199, Aug. 31, 1963, p. 898, 899.

Brief review of an investigation to determine whether ruby grown by a vapor-phase process, which produced orange-colored ruby (rather than the normal pink), is a potential maser material. The paramagnetic spectrum of the orange ruby shows the normal Cr^{+3} lines, the measurement of which in an alumina energy-level diagram shows that the broad line is coincident with the idler transitions when the crystal is being operated in the double-pump position. This produces a rapid relaxation path similar to that used in the first successful maser. It is noted that this material may prove to be superior to the normal pink ruby as maser material.

A63-23904**THE LASER AND ITS APPLICATION TO METEOROLOGY.**

G. G. Goyer and R. Watson (National Center for Atmospheric Research, Boulder, Colo.). American Meteorological Society, Bulletin, vol. 44, Sept. 1963, p. 564-570. 22 refs.

General discussion of the principle of the laser and its use in atmospheric studies. The characteristics of the laser beam are briefly described. It is seen that, when using the laser for meteorological investigations, the choice of wavelength is restricted by atmospheric and particulate absorption, solar background radiation, and, in the far IR, by the suitability of the optics, the light amplifiers, and the available detectors. Considered is the application of the laser to studies of radiation scattering in the atmosphere, and its use in radar-type instruments to determining cloud structures.

A63-23922**RADAR OBSERVATIONS OF VENUS IN THE SOVIET UNION IN 1962 [RADIOLOKATSIONNYE NABLIUDENIIA VENERY V SOVETSKOM SOIUZE V 1962 GODU].**

V. A. Kotelnikov, V. M. Dubrovin, B. A. Dubinskii, M. D. Kislik, B. I. Kuznetsov, I. V. Lishin, V. A. Morozov, G. M. Petrov, O. N. Rzhiga, G. A. Sytsko, and A. M. Shakhovskoi (Academy of Sciences, Radio Engineering and Electronics Institute, Moscow, USSR).

Akademiia Nauk SSSR, Doklady, vol. 151, July 21, 1963, p. 532-535. In Russian.

Presentation of some results of Venus radar probes in which radar sensitivity was improved 6-fold relative to previous observations in 1961, by employing a parametric ruby-maser amplifier at the receiver input, and several other improvements. Presented are graphs showing: (1) the signal spectrum obtained at a filter pass band of 1 cps, (2) the distribution of FM signals reflected by Venus at filter pass bands of 1 and 4 cps, (3) the variation in distance between the Earth and Venus relative to the calculated value, and (4) the reflected-signal envelope.

A63-24011**LASERS. II.**

Aubrey Harris.

Wireless World, vol. 69, Sept. 1963, p. 426-431.

General discussion of the principles and applications of the laser including the gaseous, liquid, and semiconductor-junction types. The basic phenomena involved in a gas-discharge laser are outlined, and a typical helium-neon laser is described. The liquid laser and lasers using a gallium arsenide semiconductor crystal are briefly described. Laser applications considered include communications, electronic gyroscopes, and precision metrology.

A63-24172**DESIGN SPECIFICATIONS FOR OPTICAL LASER RUBY RODS.**

Nelson B. Piper, Jr. (Valpey Crystal Corp., Holliston, Mass.). Microtechnic, vol. 17, no. 2, 1963, p. 59-63.

Discussion of the practical limits to which the important mechanical and optical parameters of a laser can be controlled by precision fabrication. Included are methods for controlling values of threshold level, beam divergence, and the reflectivity of end coatings. Also given are methods for determining flatness, tolerance on length and diameter, and orientation of the ruby rod with respect to one of its crystallographic axes. Ruby fabrication techniques are also indicated.

A63-24205**LASERS - GENERATION OF LIGHT BY STIMULATED EMISSION.**

Bela A. Lengyel (Hughes Aircraft Corp., Research Laboratories, Malibu, Calif.). New York, John Wiley and Sons, Inc., 1963. 125 p. \$6.95.

Review of the laser state-of-the-art and its present level of achievement. The book, a reference source for both student- and graduate-level scientists, emphasizes principle rather than engineering design, and includes background material on light and radiation. Described are: (1) Maiman's ruby laser, (2) Javan's gas laser, (3) solid- and liquid-state lasers, (4) analytical problems, and (5) applications and development. Current development problems are explored, and information published after completion of the text is reported in a supplement.

A63-24208**SEMICONDUCTOR LASERS.**

Benjamin Lax (Massachusetts Institute of Technology, Lincoln Laboratory, Solid State Div., and National Magnet Laboratory, Cambridge, Mass.).

Science, vol. 141, Sept. 27, 1963, p. 1247-1255. 23 refs. Army-Navy-USAF-supported research.

Discussion of the physical and optical properties of typical gallium arsenide diodes developed for low-temperature operation. Considered are probable mechanisms for the electron transitions which give rise to recombination and, hence, emission. Also discussed are the location of the inverted or active region, and the nature of the trapping or guiding of electromagnetic waves.

A63-24209**MUTATIONS OF SPIN MAGNETIZATION IN TWO-LEVEL MASER OSCILLATORS.**

I. M. Firth (St. Andrews University, School of Natural Philosophy, St. Andrews, Scotland).

Physica, vol. 29, Aug. 1963, p. 857-869. 13 refs.

Semiclassical description of the coupling of the spin system to the cavity radiation field in a two-level maser oscillator. The pertinent differential equations of the formalism are solved for likely experimental parameters, by use of an analog computer, to provide a general theoretical basis for observations.

A63-24272**SOME DEMONSTRATIONS OF THE PROPERTIES OF OPTICAL MASERS.**

C. Hilsum and P. G. R. King (Services Electronics Research Laboratory, Baldock, Hertfordshire, England).

Contemporary Physics, vol. 4, Aug. 1963, p. 435-444.

Description of the characteristics and mode of operation of gas discharge and gallium-arsenide semiconductor lasers. Discussed are open optical bench masers, high resonator fields, engineered lasers, the "twinkle" effect, resonator modes, laser metrology, and laser construction.

A63-24382**A SOLID-STATE MOLECULAR RUBY-AMPLIFIER AT LIQUID-NITROGEN TEMPERATURE [EIN FESTKÖRPER-MOLEKULAR-VERSTÄRKER MIT RUBIN BEI DER TEMPERATUR VON FLÜSSIGEM STICKSTOFF].**

Hans Werner Fock (Heinrich-Hertz-Institut, Berlin, Germany).

Nachrichtentechnische Zeitschrift, vol. 16, May 1963, p. 233-239. In German.

Investigation of ruby maser properties in the 3- and 1.25-cm wavelength regions of the RF spectrum, at room temperature and at the boiling point of liquid nitrogen, as a function of chromium concentration, magnetic-field intensity, and RF excitation. A method is developed for the determination of the ruby-crystal c-axis with the aid of an RF-spectrograph. Discussed is a molecular ruby-amplifier designed to function with liquid nitrogen or liquid helium. Some test results obtained with the device are included.

A63-24808**SUPERCONDUCTING-SOLENOID TRAVELING-WAVE MASER SYSTEM.**

S. Okwit, K. Siegel, and J. G. Smith (Cutler-Hammer, Inc., Airborne Instruments Laboratory, Deer Park, N. Y.).

IEEE, Proceedings, vol. 51, Sept. 1963, p. 1236.

Brief description of an S-band traveling-wave maser (TWM) system that operates at 4.29K and is driven by a lightweight air-core superconducting magnet. Effective maser noise temperatures were measured over the tuning band using a hot and cold load noise generator. The results of these measurements are tabulated.

A63-24809**STIMULATED RAMAN EMISSION IN A NORMAL RUBY LASER.**

M. Geller, D. P. Bortfeld, W. R. Sooy, and E. J. Woodbury (Hughes Aircraft Co., Aerospace Group, Culver City, Calif.).

IEEE, Proceedings, vol. 51, Sept. 1963, p. 1236, 1237.

Analysis of the stimulated Raman emission obtained in a number of organic liquids by inserting them in the feedback path of a giant-pulse ruby laser. Indicated is the time development of a typical Woodbury-Raman laser pulse. The pulse amplitude increases from essentially zero to full strength (about 5 Mw) in less than 1 nsec (the limit of resolution of the detector).

A63-24813**DONOR-DIFFUSED GALLIUM ARSENIDE INJECTION LASERS.**

C. E. Kelly (IBM Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

IEEE, Proceedings, vol. 51, Sept. 1963, p. 1239, 1240.

Fabrication of n on p GaAs injection lasers by diffusion of donors into a p-type substrate. The laser units fabricated were rectangular parallelepipeds with sawed (nonreflecting) edges in the long dimension, and cleaved (reflecting) ends perpendicular to the long dimension, the junction being parallel to the top surface. Optical observations of the diodes in lasing condition show the light to be emitted from several points in a narrow active region almost coincident with the n-p junction.

A63-24816**CONTINUOUS STIMULATED EMISSION FROM GaAs DIODES AT 77°K.**

M. Pilkuhn, H. Rupprecht, and J. Woodall (IBM Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

IEEE, Proceedings, vol. 51, Sept. 1963, p. 1243.

ARPA-Navy-DOD-sponsored research.

Study in connection with the preparation of low threshold GaAs laser materials. Indicated is the appearance for an unsilvered GaAs diode of stimulated emission at 8.2 ma (current density: 400 amps/cm²). This unit was operated continuously at three times the threshold current without noticeable heating.

A63-24817**A RELATION BETWEEN THE CURRENT DENSITY AT THRESHOLD AND THE LENGTH OF FABRY-PEROT TYPE GaAs LASERS.**

M. Pilkuhn and H. Rupprecht (IBM Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

IEEE, Proceedings, vol. 51, Sept. 1963, p. 1243, 1244.

ARPA-Navy-DOD-sponsored research.

Analysis of GaAs lasing diodes of different lengths, fabricated in the same manner and from the same material. Current density j_t at threshold is plotted as a function of l/length for two sets of samples. It is seen that the longer units have the lower threshold current density, and that a linear relation exists between j_t and reciprocal length.

A63-24822**INDUCED GAMMA-RAY EMISSION.**

G. C. Baldwin, J. P. Neissel, and L. Tonks (General Electric Co., Advanced Technology Laboratories, Schenectady, N. Y.).

IEEE, Proceedings, vol. 51, Sept. 1963, p. 1247, 1248.

Discussion of stimulated maser γ -ray emission. The work of Vali and Vali is acknowledged, and agreement is expressed with their conclusion that nuclear reactions must be used to achieve high concentrations of excited nuclear states. However, the particular method they suggest, in which the isomeric nuclei are obtained by beta decay, is of relatively low yield, and the isomer Rh^{103} is of very short half-life. It is suggested that higher yields and more favorable working times will be achieved through use of a Szilard-Chalmers separation with certain longer-lived isomers produced directly by (n, γ) reactions. Stressed is the restricted nature of the criticality implicit in Vali and Vali's equation for the "condition for criticality." A reply by the latter two is included.

A63-24827**A MOLECULAR BEAM HIGH POWER METER.**

W. K. Kahn (Brooklyn, Polytechnic Institute, Microwave Research Institute, Brooklyn, N. Y.).

IEEE, Proceedings, vol. 51, Sept. 1963, p. 1251, 1252.

Army-Navy-sponsored research and Contract No. AF 18(600)-1505.

Brief description of techniques which utilize molecular beams to measure high microwave power. The principles described should become useful for measuring power in the neighborhood of 1 Mw at X-band. Considered is the force experienced by a molecule such as NH_3 in an applied dc electric field, with regard to the design of the focusing or state-separating mechanism of the ammonia maser. Two possible realizations of such a device are outlined.

A63-24828**INTERMODULATION DISTORTION IN GaAs INFRARED EMITTERS.**

L. M. Vallese, M. King (International Telephone and Telegraph Corp., Federal Laboratories Div., Nutley, N. J.), and C. A. Parry (International Telephone and Telegraph Corp., Communications Systems Div., Paramus, N. J.).

IEEE, Proceedings, vol. 51, Sept. 1963, p. 1252, 1253.

Experimental study of the linearity of modulation of GaAs IR emitters, in terms of their application as communication links. Distortion may be produced by nonlinearities associated with the input current-voltage characteristic and with the mechanism of photon emission. Experimental studies indicate that the former effect is the sole cause of the distortion.

A63-24849

EFFECTS OF OUTPUT COUPLING ON OPTICAL MASERS.

P. A. Miles (Massachusetts Institute of Technology, Laboratory for Insulation Research, Cambridge, Mass.) and I. Goldstein (Raytheon Co., Space and Information Systems Division, Research and Development Laboratory, Bedford, Mass.).

IEEE Transactions on Electron Devices, vol. ED-10, Sept. 1963, p. 314-318. 11 refs.

Contract No. AF-AFOSR-62-317.

Consideration of the effects of output coupling on the threshold and power output of both ground- and excited-terminal state lasers. The application of this theory to the ruby laser indicates high internal losses under strong excitation conditions. The results should also be applicable to a multimode resonator and inhomogeneously broadened atomic lines, if the oscillating mode structure and the amplified fluorescence losses from nonoscillating modes are independent of output coupling and of excitation rate.

A63-25055

ON MASER RATE EQUATIONS AND TRANSIENT OSCILLATIONS.

C. L. Tang (Raytheon Co., Research Div., Waltham, Mass.).

Journal of Applied Physics, vol. 34, Oct. 1963, p. 2935-2940. 20 refs.

Derivation of macroscopic maser rate equations, from the Boltzmann equation for the density matrix of the atomic systems and Maxwell's equations for the radiation fields. If the linewidth corresponding to the inverse of the coherence time of the atomic systems is much larger than the cavity linewidth and the natural linewidth of the atomic emission, it is shown, making use of a WKB-type of approximation procedure, that the first-order equations describing the radiation field and the atomic systems are the rate equations of Stutz and deMars. However, if the radiation cavity linewidth is much larger than the atomic linewidths, the so-called reaction field principle of Anderson can be used. Both sets of rate equations have stable steady-state solutions.

A63-25060

EFFECT OF A SMALL STOKES SHIFT ON THE OPERATION OF THREE-LEVEL MASERS.

Peter J. Warter, Jr. (Princeton University, Dept. of Electrical Engineering, Princeton, N.J.).

Journal of Applied Physics, vol. 34, Oct. 1963, p. 2966-2972. 18 refs.

AEC-supported research and NSF Contract No. GP-579.

Consideration of the effect of a Stokes shift on the operation of masers in which the terminal state is either the ground state or some other state with an appreciable probability of population by thermal excitation. The analysis uses the simplest model of a three-level maser, in which there are only two relevant electronic states, one being the ground state. Effects considered include shifting of the peak in the net gain to longer wavelengths, temperature effects, and the reduction in the upper-state population at threshold, with the associated reduction in the threshold pump energy.

A63-25115

SCATTERING OF OPTICAL PULSES FROM A NONEQUILIBRIUM PLASMA.

S. E. Schwarz (California Institute of Technology, Dept. of Electrical Engineering, Pasadena, Calif.).

IEEE, Proceedings, vol. 51, Oct. 1963, p. 1362.

JPL-supported research and Contract No. AF 19(604)-8052.

Experimental investigation of the use of giant-pulse-laser light to study the characteristics of nonequilibrium plasmas. The experimental apparatus is briefly described, and the scattering of a light pulse (0.1 joules in less than 10^{-7} sec) by a helium plasma is discussed.

A63-25118

CONTINUOUS OPTICAL SUM FREQUENCY GENERATION.

N. I. Adams and P. B. Schoefer (Perkin-Elmer Corp., Optical Maser Dept., Norwalk, Conn.).

IEEE, Proceedings, vol. 51, Oct. 1963, p. 1366, 1367.

Description of a technique to obtain the optical sum of two CW laser beams. Two gas lasers operating at 6328 Å and 1.1523 μ were used, with input powers of 1.2×10^{-3} watts and 2.5×10^{-3} watts, respectively. The output power obtained at 4085 Å was 4×10^{-14} watts.

A63-25277

DETECTION OF SCATTERING LAYERS IN THE UPPER ATMOSPHERE (60-140 km) BY OPTICAL RADAR.

G. Fiocco (Massachusetts Institute of Technology, Dept. of Geology and Geophysics, Cambridge, Mass.) and L. D. Smullin (Massachusetts Institute of Technology, Dept. of Electrical Engineering, and Research Laboratory of Electronics, Cambridge, Mass.).

Nature, vol. 199, Sept. 28, 1963, p. 1275, 1276.

USAF-Navy-supported research and Grant No. NsG-419.

Brief review of observations of optical echoes from atmospheric constituents (presumably dust) at heights of 60-140 km, using an optical radar consisting of a ruby laser delivering short pulses of approximately 50 nanosec, 0.5 joule at a wavelength of 6940 Å. Plotted are the results of the observations for July 28-31, 1963, covering the period of the δ-Aquarids meteor shower. The sums of the photoelectrons obtained in successive 10-km-range intervals are displayed for each night.

A63-25278

SPECTRA OF GIANT PULSES FROM A RUBY LASER.

D. J. Bradley, A. W. DeSilva, D. E. Evans, and M. J. Forrest

(U.K. Atomic Energy Authority, Culham Laboratory, Abingdon, Berkshire, England).

Nature, vol. 199, Sept. 28, 1963, p. 1281, 1282.

NSF-supported research.

Investigation of the spectral character of a giant pulse emitted by a ruby laser, in order to determine the suitability of this source for plasma light-scattering experiments. The spacing of the lines contained within a single order is examined, and it is found that the wave-number separations are frequently small integral multiples of the characteristic shift in wave number.

A63-25412

SOME PROBLEMS ASSOCIATED WITH THE GENERATION OF OPTICAL RADIATION [NEKOTORYE VOPROSY GENERATSII OPTICHESKOGO IZLUCHENIIA].

O. N. Krokhin.

Akademiia Nauk SSSR, Vestnik, Aug. 1963, p. 62-69. In Russian.

Brief review of recent developments in laser technology. Examined are problems associated with the realization of new concepts in the generation, modulation, and reception of coherent optical radiation. Also examined are the problems involved in the design of new lasers to operate at certain frequency bands, and in the development of techniques to improve laser performance and characteristics.

A63-25765

ATOMIC STANDARDS OF TIME.

R. D. Haun, Jr. (Westinghouse Electric Corp., Research Laboratories, Pittsburgh, Pa.).

IN: AMERICAN INSTITUTE OF AERONAUTICS AND ASTRO-NAUTICS, AND USAF, VEHICLE DESIGN AND PROPULSION MEETING, DAYTON, OHIO, NOV. 4-6, 1963, PROCEEDINGS. New York, American Institute of Aeronautics and Astronautics, 1963, p. 106-114. 43 refs.

Description of the basic operating principles of several different types of atomic frequency standards. The factors limiting their stability and accuracy are listed, and estimates are given for the values of stability and accuracy which they can provide. The types of atomic frequency standards which are described include: cesium atomic beam frequency standard; gas cells; and ammonia, hydrogen, and optical masers.

A63-26026

USE OF OPTICAL MASERS AS TRANSDUCERS FOR SEISMOGRAPHS.

Howard W. Leaf (USAF, Office of Scientific Research, Geophysics Div., Washington, D.C.).

OAR Research Review, vol. 11, Sept. 9, 1963, p. 8-12.

Brief description of a vertical-component optical maser seismograph. The general advantage of the gaseous maser for this application is seen to be its high sensitivity and its great dynamic range. A schematic diagram of the laser seismograph is presented.

A63-26033

LASER AND COHERENT OPTICAL RADIATION.

S. Deb, P. K. Chowdhury, and M. K. Mukherjee (Jadavpur University, Dept. of Telecommunication Engineering, Calcutta, India).

Journal of Scientific and Industrial Research, vol. 22, Aug. 1963, p. 314-334. 155 refs.

Brief description of recent developments in the field of lasers. The basic principle of laser operation is outlined and a simple mathematical approach to the theory of laser indicated. The performance of various types of resonators used in the optical range is discussed. A classification of the different types of lasers developed so far is proposed, and representative experimental systems illustrating the various classes are described. The results obtained are also briefly reviewed. The significance of coherent optical emission is explained and the extent of coherence achieved so far with lasers is mentioned. The outstanding properties of coherent laser output are enumerated and the possible scientific and technological applications of these are described.

A63-26068

SIMPLE METHOD OF QUANTUM-EFFICIENCY MEASUREMENT.

N. C. Chang (General Telephone and Electronics Laboratories, Inc., Palo Alto, Calif.).

Optical Society of America, Journal, vol. 53, Nov. 1963, p. 1315-1317.

Presentation of a simplified indirect method for the measurement of quantum efficiencies of fluorescent materials. The technique is based on a comparison between the fluorescence of a material of known (relative or absolute) quantum efficiency and that of a material the quantum efficiency of which is to be measured. The procedure eliminates the need to determine the spectral distribution of excitation, and narrows the spectral response of the photodetector to a small spectral range. A technique whereby the problem of the spatial distribution of fluorescence can be eliminated is described.

1964

IAA ENTRIES

A64-10037

INVESTIGATION OF THE DIRECTIVITY OF A LASER.

M. P. Vaniukov, V. I. Isaenko, and V. A. Serebriakov (State Optical Institute, Leningrad, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 44, May 1963, p. 1493-1496.)

Soviet Physics - JETP, vol. 17, Nov. 1963, p. 1004-1006. Translation.

Experimental investigation of the directivity of the stimulated radiation from lasers with square, rectangular, and octagonal cross sections, in order to determine that this radiation may be distributed over several discrete directions. The existence of such directions is ascribed to the formation of additional closed paths for the generating rays due to the multiple reflections at the parallel sidewalls.

A64-10180

PROPERTIES OF A FOUR-LEVEL LASER.

Iu. A. Anan'ev, V. P. Gribkovskii, A. A. Mak, and B. I. Stepanov (Academy of Sciences, Institute of Physics, Minsk, Belorussian SSR).

(Akademiia Nauk SSSR, Doklady, vol. 150, May 1963, p. 507-510.)

Soviet Physics - Doklady, vol. 8, Nov. 1963, p. 471-473.

Translation.

A64-10232

SOME POTENTIALITIES OF OPTICAL MASERS.

B. M. Oliver (Hewlett-Packard Co., Palo Alto, Calif.).

(IRE, Proceedings, vol. 50, 1962, p. 135.)

IN: INTERSTELLAR COMMUNICATION.

Edited by A. G. W. Cameron.

New York and Amsterdam, W. A. Benjamin, Inc., 1963, p. 207-222.

Presentation of the possibilities offered by optical masers in several areas, particularly in the field of space communication. Optical masers also offer the possibility of producing far tighter beams of radiation than have heretofore been possible. Such beams will allow efficient communication over great distances. Small antennas suffice even for interplanetary distances, but for interstellar distances the larger antennas required are impractical, and optical systems are not competitive with decimeter and microwave radio systems. Highly directive beams make possible optical radar and detection schemes of heretofore unachievable resolving power. For certain space applications where the receiver may be in an inaccessible location such as a satellite, coherent optical beams may be economical for the transmission of power.

A64-10233

INTERSTELLAR AND INTERPLANETARY COMMUNICATION BY OPTICAL MASERS.

R. N. Schwartz (Institute for Defense Analyses, Washington, D. C.) and C. H. Townes (Massachusetts Institute of Technology, Cambridge, Mass.).

(Nature, vol. 190, 1961, p. 205.)

IN: INTERSTELLAR COMMUNICATION.

Edited by A. G. W. Cameron.

New York and Amsterdam, W. A. Benjamin, Inc., 1963, p. 223-231. 10 refs.

Discussion of the possibility of developing maser oscillators and other apparatus in or near the optical region which will allow the beaming of detectable light signals between planets of two stars separated by a number of light-years. The chance that broadcasts from another society approximately as advanced as we are could be detected by present telescopes and spectrographs is discussed, together with appropriate techniques now available for detection. Communication between planets within our own stellar system by beams from optical masers appears a fortiori quite practical. In order to detect signals beamed at us from another more advanced civilization, it is suggested that, perhaps, it would be appropriate to examine high resolution stellar spectra for lines which are unusually narrow, at peculiar frequencies, or varying in intensity.

A64-10244

FERROELECTRIC AND PYROELECTRIC MATERIALS.

Augustus L. Stanford, Jr.

Sperry Engineering Review, vol. 16, Fall 1963, p. 20-23.

Discussion of some of the characteristics of ferroelectrics and pyroelectrics and their applications. The possibility of using ferroelectric devices based on the nonlinear dependence exists between the permittivity and the applied electric field strength for these materials is considered. Such a device, a ferroelectric variable capacitor which is the basis for a microwave ferroelectric switch, is briefly described. The uses of pyroelectric materials noted include applications in laser instrumentation.

A64-10273

PROPERTIES OF TRANSITION-TYPE QUANTUM AMPLIFIERS

[SVOISTVA PROKHODNYKH KVANTOVYKH USILITELEI].

V. V. Lebedeva and I. V. Lebedev.

Optika i Spektroskopiia, vol. 15, Sept. 1963, p. 413-420. 12 refs. In Russian.

Discussion of the characteristics of lasers with both dielectric and metal mirrors. It is shown that a unidirectional (input-correlated) laser with dielectric mirrors can be designed by eliminating

the reflection of the incident signal from the input and its amplification in the direction of the input. Calculated are the amplification factors of symmetrical lasers with dielectric mirrors and metallic mirrors for various activity values of the medium. The advantages of dielectric mirrors over metallic mirrors are demonstrated, along with the possibility of achieving amplification factors in the order of 10 to 20 db using dielectric mirrors.

A64-10276

INVESTIGATION OF THE OUTPUT POWER OF A NEON-HELIUM LASER AS A FUNCTION OF VARIOUS PARAMETERS [ISSLEDOVANIE VYKHODNOI MOSHCHNOSTI OPTICHESKOGO GENERATORA NA SMESI NEONA I GELIJA OT RAZLICHNYKH PARAMETROV]. N. G. Basov, E. P. Markin, and V. V. Nikitin. *Optika i Spektroskopiia*, vol. 15, Sept. 1963, p. 436-438. In Russian.

Investigation of the dependence of the output power of a neon-helium laser upon the diameter and shape of the discharge tube, discharge length, mixture pressure, magnitude of pumping, and mirror transmission factor. The results obtained with tubes of various diameters are presented in graphs.

A64-10419

ENHANCEMENT OF SECOND HARMONIC POWER GENERATED BY A DIELECTRIC CRYSTAL INSIDE A LASER CAVITY. J. K. Wright (Ministry of Aviation, Signals Research and Development Establishment, Christchurch, Hants., England). *IEEE, Proceedings*, vol. 51, Nov. 1963, p. 1663.

This predicted enhancement was observed using an adenosine diphosphate crystal aligned in the phase-matching direction. The laser used was an Nd^{3+} -doped calcium-tungstate crystal laser placed between two external dielectric reflectors.

A64-10422

POWER-DEPENDENT SPLITTING OF AXIAL MODES IN RUBY LASERS.

W. Heinlein and D. Roess (Siemens and Halske AG, Central Laboratories, Munich, Germany). *IEEE, Proceedings*, vol. 51, Nov. 1963, p. 1667, 1668.

Description of experimental observations of axial-mode splitting in a 40.1mm-long ruby laser, using a photodiode to determine the photobeats between the axial modes. The beat frequency between adjacent modes generated in the photodiode was fed to a tunable mixing amplifier. A series of oscilloscopic records of the laser output are presented and discussed.

A64-10423

RADIOFREQUENCY BEATS BETWEEN COMPONENTS OF SPLIT AXIAL MODES IN RUBY LASERS.

Dieter Roess (Siemens and Halske AG, Central Laboratories, Munich, Germany). *IEEE, Proceedings*, vol. 51, Nov. 1963, p. 1668, 1669.

Description of an "exfocal" pumping technique used in experiments on the splitting of axial modes in a ruby laser. The method involves placing the laser and the pumping source symmetric to one another at the respective foci of the major axis of a mirror consisting of an ellipsoid of revolution. For this configuration, the pump light is incident on the laser in exactly rotational symmetry, and if the ruby rod is orientated at 0° to the crystal axis, this leads to rotational-symmetrical absorption of the pump light, and, furthermore, to a symmetrical expansion of the laser during the pumping pulse. This results in periodical relaxation spikes and in a longer duration of the laser emission than in other arrangements.

A64-10437

AMMONIA MOLECULAR OSCILLATOR EMPLOYING A DISK RESONATOR.

A. I. Barchukov, A. M. Prokhorov, and V. V. Savranskii. (*Radiotekhnika i Elektronika*, vol. 8, Mar. 1963, p. 438, 439.) *Radio Engineering and Electronic Physics*, Mar. 1963, p. 385, 386. Translation.

Brief description of a disk resonator used as the resonator for an ammonium laser operating at a wavelength of 1.25 cm. The volume of the resonator is 400 cm^3 , exceeding by about a factor of 50 the volume of cylindrical resonators generally used. The working volume of the resonator is about 200 cm^3 . A schematic of the system is presented.

A64-10533

INSTABILITY OF THE GENERATION OF MONOCHROMATIC EMISSION IN SOLID-STATE LASERS [O NEUSTOICHIVOSTI REZHIMA GENERATSII MONOKHROMATICHESKOGO IZLUCHENIYA V OPTICHESKIKH KVANTOVYKH GENERATORAKH NA TVERDOM TELE].

T. I. Kuznetsova and S. G. Rautian (Academy of Sciences, Lebedev Physics Institute, Moscow, USSR).

Fizika Tverdogo Tela, vol. 5, Aug. 1963, p. 2105-2115. 12 refs. In Russian.

Discussion of the plane solutions of the wave equation for a layer with a negative absorption factor. One of the solutions is postulated monochromatic and "strong" (in the sense that it causes saturation); the other equations are considered to be weak to an extent that their effect upon dielectric permeability is negligible. Defined is the condition for the increase in time of the weak solutions, which leads to an instability in the production of monochromatic emission. Noted is the appreciable effect of the medium's nonuniformity caused by saturation, and that all the weak solutions would be damped solutions if this nonuniformity were neglected. A rigorous analysis shows that near transition frequency, there forms a frequency region in which increasing weak fields may occur if the amplitude of the strong field is sufficiently great. It is shown that the instability criterion depends upon the ratio of the lifetime of the upper state to the lifetime of the lower state, the transition between which is used for generation of emission.

A64-10558

MODE SELECTION IN AN APERTURE-LIMITED CONCENTRIC MASER INTERFEROMETER.

Tingye Li (Bell Telephone Laboratories, Inc., Murray Hill, N.J.). *Bell System Technical Journal*, vol. 42, Nov. 1963, p. 2609-2620. 14 refs.

Analysis of the mode-selective properties of a concentric maser interferometer with a limiting aperture in its mid-plane. Two of the lowest-order transverse modes and their losses for the infinite-strip geometry are computed by solving the associated integral equations by the method of successive approximations. The apertured concentric interferometer is found to be more mode-selective than the apertureless interferometer, or the Fabry-Perot interferometer with parallel plane mirrors. Computed results indicate that the optimum aperture size for maximum mode selectivity is approximately the size of the major lobe of the diffraction pattern of the dominant mode at the aperture plane. However, the maximum selectivity attainable does not exceed that of the "comparable" confocal system. The latter system is not very practical because it requires either very long resonator lengths or very small mirrors.

A64-10568

ON THE SPECTRUM OF OPTICAL WAVES PROPAGATED THROUGH THE ATMOSPHERE.

D. C. Hogg.

Bell System Technical Journal, vol. 42, Nov. 1963, p. 2967-2969.

Analysis of typical LF spectra resulting from the propagation of 0.63-micron radiation over a 2.6-km path. A vertically polarized helium-neon maser of power output 10 mw and a reflecting telescope of 9-cm diameter comprise the source. The receiver is a refracting telescope of 5-cm diam with associated filters, polarizers, and attenuators which feed a photomultiplier; it is located in the dense central region of the transmitted beam. Typical power spectra are presented and discussed.

A64-10604

RESONANCES OF THE FABRY-PEROT LASER.

S. R. Barone (TRG, Inc., Syosset, N.Y.).

Journal of Applied Physics, vol. 34, Apr 1963 (Part I), p. 831-843. 10 refs.

Contract No. AF19(604)-8817.

Investigation of the optical mode structure of a Fabry-Perot interferometer-resonator composed of two infinite strip mirrors, from the point of view of the general theory of nonspectral resonances. It is shown that the classical description of this configuration is inadequate to describe its response to highly monochromatic laser radiation and must be supplemented by a discussion of the transverse resonance behavior. This introduces a fine structure to the classical Fabry-Perot rings and implies a discrete resonance behavior for the Fabry-Perot interferometer. On the basis of a reformulation and asymptotic expansion of a previously given stationary expression, it is shown that in the high-frequency limit, the open sides of the structure can be replaced by an effective impedance boundary condition. The solution of an elementary resonance problem then yields analytic approximations for the mode shapes, characteristic oscillation frequencies, and modal lifetimes. In the common domain of validity these results are in excellent agreement with previous numerical work on this problem.

A64-10610

OPTICAL MASER CHARACTERISTICS OF RARE-EARTH IONS IN CRYSTALS.

L. F. Johnson (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

Journal of Applied Physics, vol. 34, Apr. 1963 (Part I), p. 897-909. 37 refs.

Description of laser activity in systems consisting of divalent and trivalent rare-earth ions incorporated into various host crystals. Considered are the absorption and fluorescence spectra, energy-level diagrams, wavelengths and operating temperatures, and thresholds for stimulated emission. Recent observations on the $\text{CaWO}_4:\text{Nd}^{3+}$ optical maser in continuous operation are also described.

A64-10615

LASER OPERATION WITHOUT SPIKES IN A RUBY RING.

Peter Walsh and G. Kemeny (American-Standard, Research Div., Union, N.J.).

Journal of Applied Physics, vol. 34, Apr. 1963 (Part I), p. 956, 957. 11 refs.

Brief description of pulsed laser operation produced by complete internal reflection in a ruby ring at room temperature. The linearized equations of Statz and de Mars give a good description of the steady laser operation. The lifetime of the excited Cr^{3+} ions is found to be $\sim 1 \mu\text{sec}$ under operating conditions. Short-lived transient oscillations rather than spikes were observed in the laser output. This result can be tentatively explained by assuming a cavity Q of 10^8-10^9 .

A64-10617

DIFFRACTION STUDIES WITH PLANE-PARALLEL MASER INTERFEROMETER.

W. W. Rigrod and A. J. Rustako, Jr. (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

Journal of Applied Physics, vol. 34, Apr. 1963 (Part I), p. 967, 968.

Studies using a helium-neon optical maser tube with high-quality fused quartz windows at the Brewster angle. The device supports oscillations between external plane mirrors at 6328 \AA , 1.15μ , and 3.39μ producing over 40 mw at 1.15μ and 28 mw at 3.39μ in the dominant TEM_{00} mode. Calculations of Fox and Li are verified by means of apertures inside the resonator. Patterns made with various obstacles in the resonator bear a blurred resemblance to those made with the same obstacles in the 1-cm beam outside the resonator.

A64-10621

FARADAY EFFECT AS A Q-SWITCH FOR RUBY LASER.

James L. Helfrich (Frankford Arsenal, Philadelphia, Pa.).

Journal of Applied Physics, vol. 34, Apr. 1963 (Part I), p. 1000, 1001.

Report on experiments. The single pulse obtained is 60 nano-sec wide at the base. Peak power is approximately 600 kw. There is evidence that the single pulse, though more intense, subtends a smaller angle than the normal multipulse laser beam.

A64-10663

PROPOSAL FOR BEATING TWO OPTICAL MASERS.

G. D. Mahan and J. J. Hopfield (California, University, Dept. of Physics, Berkeley, Calif.).

Journal of Applied Physics, vol. 34, May 1963, p. 1531-1534. 12 refs.

NSF-supported research.

Proposition of an experimental arrangement with which two optical masers may be made to beat to produce a far-infrared source. The beating process occurs in a semiconductor which lacks inversion symmetry, allowing the third-order process. By selecting a semiconductor with an appropriate energy gap, the energy denominators in the matrix element may be made small, enhancing the infrared intensity. Using the exciton states as the virtual intermediate states, the power output is calculated in the effective-mass approximation. For beating a ruby maser at $T = -180^\circ\text{C}$ (6934 \AA) with one at $T = 20^\circ\text{C}$ (6943 \AA), a CdSe sample at 4.2°K is proposed because its exciton energies are just higher than the maser energies. For input power of 10 kw for each energy, a 19-cm^{-1} infrared beam of over a watt is expected. The competing process of two-photon absorption heats the sample to approximately 65°K during a pulse, but this effect is not disastrous.

A64-10665

A PROPOSAL FOR A DC PUMPED RARE-EARTH LASER.

R. L. Bell (Varian Associates, Palo Alto, Calif.).

Journal of Applied Physics, vol. 34, May 1963, p. 1563, 1564.

Development of a method for minimizing the losses inherent in the collection and transmission of pumping radiation in the conventional laser. The method uses the recombination radiation to raise impurity centers in the host to optically excited states which could then be lased (normally at photon energies less than the band gap). A figure shows the elements of the scheme. It is stated that a major advantage of this scheme over the recombination laser is that the photon energy may be much lower than the absorption edge for the large band-to-band absorption of the lattice.

A64-10764

HIGH-SPEED PHOTOGRAPHS OF LASER-INDUCED HEATING.

T. J. Harris (International Business Machines Corp., Data Systems Development Laboratory, Poughkeepsie, N.Y.).

IBM Journal of Research and Development, vol. 7, Oct. 1963, p. 342-344.

Demonstration of the effects of high-energy, focused laser beams striking targets of steel, brass, and aluminum. For the light flux densities used, these photographs seem to support recent speculations that the absorption of intense laser radiation will heat the material at some depth below the surface to its vaporization temperature before the material at the surface has absorbed its latent heat of vaporization. This is thought to induce a pulse of high pressure in the underlying material and to result in the emission of the vaporized material similar to a chemical explosion.

A64-10783

GATLING-GUN LASER - NOVEL APPROACH TO OPTICAL RADAR.

Michael E. Wolff.

Electronics, vol. 36, Sept. 20, 1963, p. 25-29.

Description of a new technique for achieving high laser pulse repetition frequencies. The method involves sequential Q-switching of an array of lasers by a rotating Fabry plate, much in the fashion of the old-time Gatling gun. The result of the technique is to combine the pulse recurrence frequencies (prfs) of several laser beams along identical paths, thus achieving higher prfs than can be obtained with a single crystal. Circuit diagrams of various component circuits are presented.

A64-10921

THEORY OF LASER REGENERATION SWITCHING.

Arthur A. Vuylsteke (General Motors Corp., Defense Research Laboratories, Goleta, Calif.).

Journal of Applied Physics, vol. 34, June 1963, p. 1615-1622. 10 refs.

Development of the theory of laser regeneration switching. The rate equations are derived, and using ruby as an example, the material-cavity parameters are evaluated for a 1-cm³ rod. Steady-state solutions for $t < 0$ are given, and the equations formally integrated for $t > 0$. Using approximate solutions, three modes of laser operation, other than the normal mode, are discussed. With the first mode: the pulsed reflection mode (PRM) switched to minimum coupling, output pulses with peak powers of 17 MW and 10 nsec duration are predicted, with 2% of the initially stored energy emitted. With the second mode: the PRM switched to critical coupling, peak powers of 170 MW with pulse durations of about 8 nsec, and with about 50% of the stored energy emitted, are predicted. In the third mode: the pulsed transmission mode (PTM), peak powers of about 900 MW, pulse durations around one nsec, with 52% of the stored energy emitted, are predicted. Experimental approaches to PTM operation are briefly discussed.

A64-10931**ENERGY DENSITY DISTRIBUTION IN A POLISHED CYLINDER OF LASER MATERIAL.**

W. R. Sooy and M. L. Stitch (Hughes Aircraft Co., Culver City, Calif.).

Journal of Applied Physics, vol. 34, June 1963, p. 1719-1723.

Calculation of the flux distribution inside a smooth-walled laser cylinder for two limiting assumptions about the nature of the incident pumping flux. The idealized case of a line source at one focus of an elliptical reflector producing a convergent cylindrical wavefront at the other focus leads in the expected way to a singularity at the center of the crystal, and for sufficiently large values of the product of the doping concentration and diameter, the flux density goes through a minimum before increasing. This corresponds to the relatively rare physical situation in which the laser crystal is much larger than the pump source and both are very small compared to the reflector. A much more realistic assumption of isotropic flux distribution cannot be integrated in closed form and required a machine calculation. This reveals that the distribution is strongly dependent on doping, and that for light doping the flux density in the central region is approximately three-fold higher than in the peripheral regions. This is used as a hypothesis to explain low observed laser efficiencies by postulating that for typical operation the central region is undergoing laser action while the more voluminous peripheral region is absorbing pump energy and converting it to fluorescence. Some experimental evidence to support this hypothesis is obtained by measurements of the inversion, averaged over the whole crystal, by means of absorptivity measurements. It has been shown that laser action commences while the crystal is still, on the average, absorbing.

A64-10949**INTENSITY DISTRIBUTION OF RUBY LASER BEAMS.**

T. V. George (Illinois, University, Gaseous Electronics Laboratory, Urbana, Ill.), L. Slama (Atomic Energy Commission, Saclay, France), and M. Yokoyama (Osaka University, Osaka, Japan). *Applied Optics*, vol. 2, Nov. 1963, p. 1198-1201.

USAF-supported research.

Experimental investigation of the intensity distribution of the ruby laser beam at large angles. Unexpected intense side lobes parallel to the plane of polarization were observed. The densitometric curves do not exhibit any sharp decrease in intensity with angular deviation in the direction perpendicular to the plane of polarization. But in the plane of polarization, there is a sharp decrease in intensity with angle, and in that direction there are no side lobes. It is observed that the intensity of the observed light even at an angle 80° is reduced only by a factor of 10³ from that of the forward beam. This is probably due to the scattering of the laser beam by dielectric coating of the end surface of ruby crystal or crystal itself.

A64-10950**He-Ne LASER AS SOURCE FOR LIGHT SCATTERING MEASUREMENTS.**

David H. Woodward (Colorado, University, Boulder, Colo.). *Applied Optics*, vol. 2, Nov. 1963, p. 1205-1207.

NSF-supported research.

Comparison of the qualities of the continuous He-Ne laser as a monochromatic source for light scattering studies relative to conventional sources, such as a bright line from the spectrum of a mercury arc lamp. The scattering was produced by spherical polystyrene latex particles in water. The latex sizes were determined by electron microscopy and supplied by Vanderhoff. From the curves shown in a figure, the light scattering experimental values for the particle sizes appear to be slightly less than the values given by Vanderhoff. It is also evident that the experimental curves do not show quite as much fluctuation in intensity as the theoretical curves indicate. This is partly due to the fact that these data are for a large number of scattering particles in a large volume, whereas the theory gives the scattering distribution of a single particle. Also, since rather high volume concentrations of particles are used, there is some multiple scattering.

A64-11034**INITIAL OSCILLATION BEHAVIOR OF TOROIDAL RUBY LASERS AS A FUNCTION OF PUMPING PERFORMANCE [EINSCHWINGVERHALTEN TORISCHER RUBIN-LASER IN ABHÄNGIGKEIT VON DER PUMPLEISTUNG].**

Harald Hantsche and Dieter Röss (Siemens und Halske AG, Zentral-Laboratorium, Munich, Germany).

Zeitschrift für Naturforschung, vol. 18a, Aug.-Sept. 1963, p. 1020, 1021. In German.

Presentation of the results of measurements of the damping period, relaxation oscillation, and relaxation period of a toroid of ruby as a function of the pumping performance at various temperatures. The results, shown graphically, demonstrate that the theories of optical single-mode resonators cannot be used to describe the oscillation behavior of the toroidal ruby laser.

A64-11075**NOTE ON HOLE BURNING MODEL OF OSCILLATION FOR RUBY LASERS.**

A. J. DeMaria (United Aircraft Research Laboratories, East Hartford, Conn.).

Applied Optics, vol. 2, Oct. 1963, p. 1085.

Acknowledgment that the micropulse ensemble and the simultaneous oscillation at two optical frequencies corresponding to eigenwavelengths of the Fabry-Perot cavity which were reported previously by DeMaria and Gagosz can be explained by the "spatial hole burning" model of operation for ruby lasers which was proposed by Tang, Stutz, and deMara.

A64-11170**LASER TECHNIQUES FOR METALS JOINING.**

W. N. Platte and J. F. Smith (Westinghouse Electric Corp., Research and Development Center, Pittsburgh, Pa.). (Western Welding Technical Conference, Palo Alto, Calif., May 9-11, 1963.)

Welding Journal, Research Supplement, vol. 42, Nov. 1963, p. 481-s-489-s. 10 refs.

Contract No. AF33(657)-9897.

Theoretical and experimental investigation of the application of placed laser pulses to make joints in semiconductor devices. The general principles of laser operation are discussed for a ruby laser. The requirements in terms of a CW and pulsed lasers are calculated from heat flow theory. Butt and edge welds were made using pulsed laser techniques on 0.010 in. thick austenitic stainless steel to confirm the calculations. Welds were also made connecting leads of gold to aluminum coated silicon surfaces on microelectronic devices. Joint properties were determined for these welds.

A64-11241**LOW-NOISE RECEIVERS.**

W. H. Higa (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.).

IN: SPACE COMMUNICATIONS.

Edited by A. V. Balakrishnan.

New York, McGraw-Hill Book Co., Inc., 1963, p. 251-272.

Review of the more important aspects of the role of low-noise receivers in a space communications system. Emphasized are the parametric amplifier and the maser, including the design considerations, the Dewar design, the maser receiving system, and the system block diagram of an S-band maser. Also briefly considered are an X-band- and a traveling-wave-maser. Future applications to space communications systems are briefly delineated.

A64-11447

RUBY OPTICAL MASERS FOR IN-FLIGHT MEASUREMENT OF HYPERSONIC FLOW FIELD PARAMETERS.

G. K. Wessel (Syracuse University, Physics Dept., Syracuse, N. Y.), H. C. Rothenberg, and B. Zendle (General Electric Co., Defense Electronics Div., Syracuse, N. Y.).

IN: ADVANCES IN THE ASTRONAUTICAL SCIENCES. VOL. XI. Edited by Horace Jacobs.

(American Astronautical Society, Annual Meeting, 8th, Washington, D. C., Jan 16-18, 1962, Proceedings.)

North Hollywood, Calif., Western Periodicals Co., 1963, p. 86-95.

Presentation of a new method for direct measurement of electron density distribution and electron velocity distribution in plasma by means of a ruby optical maser. The physical principles upon which the design of the new instrument is based are described in detail, and two applications - one to a hypersonic flow field situation and the other to a high-temperature laboratory plasma situation - are discussed. This method is proposed for measuring plasma parameters when conditions render impractical the use of more conventional instruments like Langmuir-type probes and microwave interferometers.

A64-11607

NONDESTRUCTIVE LASER PUMPING BY HIGH EXPLOSIVES.

John K. Crosby and R. C. Honey (Stanford Research Institute, Menlo Park, Calif.).

Applied Optics, vol. 2, Dec. 1963, p. 1339, 1340.

Description of a technique which allows the light from an explosive light source to pump a laser material without destroying the material. The technique has been demonstrated by pumping a neodymium-doped glass laser from a distance of 3.5 m without damaging the laser. Shown in a figure are the oscilloscope records of photomultiplier output during a shot. The records show that the pump pulse is strong enough to cause this laser to oscillate above threshold. The success of the shot proves that research into ways of improving efficiency and increasing power output of explosively pumped lasers can be performed without sacrificing a laser in each experiment.

A64-11684

INJECTION LASERS: STATE OF THE ART.

Marshall I. Nathan and Gerald Burns (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

Electronics, vol. 36, Dec. 6, 1963, p. 61-65. 28 refs.

Description of the principles of operation and properties of a laser that skips the intermediate step of optical pumping and converts dc power directly into coherent light. The injection lasers are thus more efficient and compact, and offer attractive possibilities for internal modulation, so they should be useful in the communication field. Other advantages include power conversion efficiency, observed in excess of 50%, and CW output power surpassing that of any other existing laser.

A64-11737

INJECTION-LASER SYSTEMS FOR COMMUNICATIONS AND TRACKING.

C. M. Johnson (International Business Machines Corp., Federal Systems Div., Bethesda, Md.).

Electronics, vol. 36, Dec. 13, 1963, p. 34-39. 16 refs.

Discussion of some possible applications of semiconductor injection lasers for communications and precision target tracking systems. Considered are theoretical aspects of laser communications, available bandwidths, usable signals, the characteristics of a pulse system, available transmitter power, and efficiency. An

experimental injection laser system is briefly described, as well as a hypothetical 5-Mc bandwidth link between a satellite and a ground station, in order to illustrate the requirements placed on a GaAs laser in an operational system. The characteristics of GaAs lasers are discussed, along with considerations associated with laser tracking. As an example, the problem of one space vehicle tracking another at 50 miles is briefly examined.

A64-11784

FLUCTUATIONS OF POLARIZATION AND STABILITY IN THE FREQUENCY OF A HELIUM-NEON LASER [FLUCTUATIONS DE POLARISATION ET STABILITE EN FREQUENCE D'UN LASER HELIUM-NEON].

Michel Dumont and Georges Durand (Ecole Polytechnique, Laboratoire de Physique, France).

Académie des Sciences (Paris), Comptes Rendus, vol. 257, no. 20, Nov. 13, 1963, p. 2974-2976. In French.

A helium-neon laser with internal mirrors functioning by impulses emits an infrared band whose polarization fluctuates randomly. It is shown, through a study of beats between modes, that the existence or absence of these fluctuations corresponds to determinate frequencies of the oscillating modes of Perot-Fabry. A method is obtained for the stabilization and absolute readjustment of optical frequencies at approximately 10^{-8} .

A64-11920

CALCIUM NIOBATE $\text{Ca}(\text{NbO}_3)_2$ - A NEW LASER HOST CRYSTAL.

A. A. Ballman, S. P. S. Porto, and A. Yariv (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Journal of Applied Physics, vol. 34, Nov. 1963, p. 3155, 3156.

Brief description of laser action observed in large single crystals of calcium niobate grown by the Czochralski technique and doped with trivalent neodymium, holmium, praseodymium, erbium, and thulium. The crystals were compensated with stoichiometric amounts of either Na^+ or Ti^{4+} . The thresholds of oscillation, and the wavelengths of the stimulated emissions, are presented and discussed.

A64-11922

STEADY-STATE OUTPUT POWER OF A LASER AS A FUNCTION OF THE SINGLE-PASS GAIN.

Irwin Tobias (Rutgers State University, School of Chemistry, New Brunswick, N. J.).

Journal of Applied Physics, vol. 34, Nov. 1963, p. 3200-3204.

10 refs.

Derivation of an expression which relates the output power of a laser to the measured single-pass gain. The case of a homogeneously broadened line is considered. The effects of Doppler broadening is then taken into account. In both cases, it turns out to be useful to have an expression for the steady-state population density of the relevant energy levels in terms of the gain. This expression is obtained from the gain expressed as a function of the absorption coefficient, and is used to derive the total power density.

A64-11923

SPATIAL DISTRIBUTION OF RADIATION FROM GaAs LASERS.

G. E. Fenner and J. D. Kingsley (General Electric Co., Research Laboratories, Schenectady, N. Y.).

Journal of Applied Physics, vol. 34, Nov. 1963, p. 3204-3208.

16 refs.

Investigation of the spatial distribution of the energy emitted by GaAs lasers having Fabry-Perot resonators. In general, the diodes emit several fan-shaped beams of comparable magnitude at angles up to 10° with respect to the normal of the mirrors in the junction plane. These beams have widths from $3/4^\circ$ to several degrees in the plane of the junction, and about 10° in the plane perpendicular to the junction. The radiation patterns are usually asymmetric about the normal to the polished faces of the diode, and this asymmetry is mirrored on the opposite side of the diode.

A64-11933

Q-SWITCHED $\text{CaWO}_4:\text{Nd}^{3+}$ LASER.

D. Karlsons and T. Falvey (Radio Corporation of America, Applied Research, Camden, N. J.).

Journal of Applied Physics, vol. 34, Nov. 1963, p. 3407.
Contract No. AF 30(602)-2761.

Brief description of the successful Q-switching of a CaWO_4 : Nd^{3+} laser operated at room temperature, with an output consisting of a variable number of short pulses (including the case of a single pulse), the number depending on the reflector separation. The crystal, 1/4-in. in diameter and 2 in. long, was pumped in an elliptical reflector. Q-switching was effected by means of a porro prism rotating at 24,000 rpm. The crystal end facing the prism was uncoated; the opposite end, through which the output was monitored, was coated with dielectric layers having a nominal 99% reflectivity at 1.06μ . The Q-switched laser output is discussed.

A64-11935**CRITERION FOR CONTINUOUS AMPLITUDE OSCILLATIONS OF OPTICAL MASERS.**

Jerome I. Kaplan (Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.).

Journal of Applied Physics, vol. 34, Nov. 1963, p. 3411, 3412.
USAF-Army-Navy-supported research.

Demonstration that a long-time solution having a time-varying amplitude can be obtained for a previously derived set of equations describing a three-level laser self-oscillating between the upper two levels. No attempt is made to find the particular analytic form of the solution. It is noted that the previously derived minimum condition for the pump power is much greater than that attained by Bostick and O'Connor, so that no continuous amplitude oscillation for the latter's $\text{CaF}_2:\text{U}^{+3}$ laser system should be expected.

A64-11936**MODE SELECTION PROPERTIES OF SEGMENTED ROD LASERS.**

Milton Birnbaum and Tom L. Stocker (Aerospace Corp., El Segundo, Calif.).

Journal of Applied Physics, vol. 34, Nov. 1963, p. 3414, 3415.

Review of experiments which demonstrate that segmented-rod lasers, constructed by butting together two or more laser rods with plane-parallel end faces, can considerably reduce the number of axial modes present in the laser output, as compared with the output of single-rod lasers of equal length. The favored axial modes of segmented lasers are those for which the Fabry-Perot resonance is satisfied in each segment. For the proper conditions, oscillation occurs only in the favored modes, with the resulting reduction in the number of axial modes present. Experiments with a two-segment laser are discussed.

A64-11937**PLASMA PINCH EXCITATION OF A RUBY LASER.**

Richard A. Brandewie, Joe S. Hitt, and J. M. Feldman (Carnegie Institute of Technology, Pittsburgh, Pa.).

Journal of Applied Physics, vol. 34, Nov. 1963, p. 3415, 3416.

Brief description of ruby laser excitation with a high-current theta pinch in argon. An unusually intense and well-defined output pulse is obtained from the ruby with apparently negligible heating of ruby or flash tube. The pump light is found to consist of line spectra, rather than the blackbody continuum emitted by the xenon flash tubes ordinarily employed for laser excitation.

A64-11938**TEMPERATURE LIMITATION ON CONTINUOUS OPERATION OF GaAs LASERS.**

S. Mayburg (General Telephone and Electronics Laboratories, Inc., Bayside, N. Y.).

Journal of Applied Physics, vol. 34, Nov. 1963, p. 3417, 3418.
Army-supported research.

Demonstration that it is possible to determine whether a GaAs laser will run continuously at a given heat sink temperature T if the threshold current density corresponding to T is known. The results indicate that the continuous operation of GaAs lasers at room temperature is unlikely.

A64-11971**LIGHT MODULATORS FOR WIDE FREQUENCY BANDS [LIGHT-MODULATOREN FÜR BREITE FREQUENZBÄNDER].**

W. Klockhaus.

Nachrichtentechnische Zeitschrift, vol. 16, Nov. 1963, p. 561-568.
30 refs. In German.

Survey of the principal current methods for wide-band modulation of light waves. Particular attention is given to the control of emission processes in semiconductor lasers, and the controlled electrical, magnetic, and mechanical processes used to produce the proper variation of the optical characteristics of solid and gas lasers.

A64-11996**PROPOSAL FOR A TWO-STAGE SEMICONDUCTOR LASER THROUGH TUNNELING AND INJECTION.**

Shyh Wang (California, University, Dept. of Electrical Engineering and Electronics Research Laboratory, Berkeley, Calif.).

Journal of Applied Physics, vol. 34, Dec. 1963, p. 3443-3450.
29 refs.

Grant No. AF-AFOSR 62-340.

Analysis of laser action in semiconductors, leading to the establishment of a condition for population inversion. The radiation output is found to be proportional to the deviation from the equilibrium value of the occupancy of the allowed states including the states in the conduction and valence band and also the donor and acceptor states. Possible laser levels are discussed. A scheme is proposed for laser action in covalent semiconductors where the top of the valence band and the bottom of the conduction band do not occur at the same value of k. The scheme consists of simultaneously tunneling electrons into the (000) valley of the conduction band and injecting holes into the valence band.

A64-12009**DETERMINATION OF R_1 LINEWIDTHS IN RUBY USING A PULSED RUBY LASER.**

R. L. Aagard (Minneapolis-Honeywell Regulator Co., Honeywell Research Center, Hopkins, Minn.).

Journal of Applied Physics, vol. 34, Dec. 1963, p. 3631, 3632. 10 refs.

Description of how a thermally tuned pulsed ruby laser has been employed to determine R_1 linewidths in ruby for temperatures between 77 and 125°K. The monochromatic beam from the laser was passed through a sample of ruby fastened to the temperature controlled cold finger of a nitrogen Dewar. A glass pick-off placed in front of the sample sent part of the beam to a monitor detector, while the rest of the light passed through the sample to a second detector. The signals from both detectors were displayed simultaneously on the screen of a dual-beam oscilloscope. Representative measurements are plotted and discussed.

A64-12010**METALLIC SCATTERING CENTERS IN CaWO_4 LASER CRYSTALS.**

J. R. Shappirio, T. R. AuCoin, and J. G. Gualtieri (U.S. Army, Electronics Research and Development Laboratory, Fort Monmouth, N. J.).

Journal of Applied Physics, vol. 34, Dec. 1963, p. 3643, 3644.

Experimental investigation which provides positive evidence for elemental iridium (or rhodium) inclusions in CaWO_4 . Two processes which could account for the metallic platelets found in and on CaWO_4 crystals are considered. These are: (1) the crucibles may be slightly soluble in molten CaWO_4 ; and (2) rhodium or iridium oxide, formed by reaction of the crucible with oxygen at the crucible-melt interface, may be decomposed at elevated temperatures to form the metal.

A64-12106**STUDIES USING HIGH INTENSITY PULSED LASER BEAMS.**

R. W. Terhune and P. D. Maker (Ford Motor Co., Scientific Laboratory, Dearborn, Mich.).

Society of Automotive Engineers, Automotive Engineering Congress, Detroit, Mich., Jan. 13-17, 1964, Paper 816B. 6 p.

Members, \$0.75; nonmembers, \$1.00.

Review of the experimental procedure used in generating very high intensity pulsed laser beams. This is followed by a discussion of the experiments to date using these high intensity beams to observe electrical breakdown at optical frequencies and nonlinear optical effects. Possible applications are also discussed briefly.

A64-12141

A THREE-CENTIMETER SOLID STATE TRAVELING-WAVE MASER. E. K. Karlova, N. V. Karlov, A. M. Prokhorov, and E. G. Solov'ev (Academy of Sciences, Physics Institute, Moscow, USSR). (*Priroda i Tekhnika Eksperimenta*, Mar.-Apr. 1963, p. 107-110.) *Instruments and Experimental Techniques*, Nov. 1963, p. 289-292. 13 refs. Translation.

Description of the construction and experimental performance of a traveling wave maser (TWM) operating in the 3-cm band and using a rod-type slow-wave structure. In a TWM, the active, negative-temperature material (having inversely populated energy levels) is placed in a waveguide, and the radiation to be amplified is propagated through the material in the form of a traveling wave. Since the absorption introduced by the material is negative, the radiation is amplified exponentially. In the experimental unit used, a gain of 20 db with a bandwidth of 20 Mc was obtained.

A64-12151

INVESTIGATION OF THE OUTPUT POWER OF A NEON-HELIUM LASER AS A FUNCTION OF VARIOUS PARAMETERS. N. G. Basov, E. P. Markin, and V. V. Nikitin. (*Optika i Spektroskopiia*, vol. 15, Sept. 1963, p. 436-438.) *Optics and Spectroscopy*, vol. 15, Sept. 1963, p. 235, 236. Translation.

[For abstract see Accession no. A64-10276 01-25]

A64-12496

ENERGY AND POWER CONSIDERATIONS IN INJECTION AND OPTICALLY PUMPED LASERS. Appendix - OPTIMUM COUPLING IN THREE LEVEL LASERS.

Amnon Yariv (Watkins-Johnson Co., Palo Alto, Calif.). *IEEE, Proceedings*, vol. 51, Dec. 1963, p. 1723-1731. 18 refs.

Review of the principles and techniques of power and energy in lasers. Both three- and four-level lasers are considered in the pulsed and continuous modes of operation. The theoretical power and energy estimates are compared with experimental data.

A64-12500

OPTICAL GIANT PULSES FROM A Q-SWITCHED LASER. Charles C. Wang (Philco Corp., Scientific Laboratory, Blue Bell, Pa.).

IEEE, Proceedings, vol. 51, Dec. 1963, p. 1767.

Presentation of a method for obtaining approximate solutions for the buildup, the main body, and the decay of high-intensity optical pulses of short duration from a Q-switched laser. It is shown that these solutions may then be matched at the boundaries to describe the entire pulse and to calculate the half-width analytically. The result is found to agree well with that obtained by numerical means.

A64-12505

A METHOD FOR DETERMINING THE THRESHOLD OF LASER MATERIALS.

A. Lempicki (General Telephone and Electronics Laboratories, Inc., Bayside, N. Y.) and R. L. Martin (Argonne National Laboratory, Argonne, Ill.).

IEEE, Proceedings, vol. 51, Dec. 1963, p. 1778, 1779.

Demonstration that a single measurement of absolute emission intensity at the peak of a fluorescent line of a material determines, in principle, the flash energy necessary to cause laser oscillation. No detailed knowledge of absorption and quantum efficiency is necessary. It is shown that, since this applies to ruby as well as any other material, and the threshold excitation of ruby is known, a comparison of the relative emission intensity of the material to that of the R_1 line of ruby also yields the desired result.

A64-12506

AN S-BAND TRAVELING-WAVE MASER WITH A 30 PER CENT TUNABLE BANDWIDTH.

D. J. Miller and H. B. Yin (Radio Corporation of America, Missile and Surface Radar Div., Applied Research Dept., Camden, N. J.).

IEEE, Proceedings, vol. 51, Dec. 1963, p. 1779, 1780.

Description of a method using chromium-doped rutile and a meander-line slow-wave maser for providing a maser having a 3-db tunable bandwidth of 30% at S band. It is seen that this method can be used to increase the tunable bandwidth until the bandwidth of the slow-wave structure of the noise temperature of the maser becomes a limiting factor.

A64-12510

A PROPOSED CLASS OF HETEROJUNCTION INJECTION LASERS. Herbert Kroemer (Varian Associates, Central Research Laboratory, Palo Alto, Calif.).

IEEE, Proceedings, vol. 51, Dec. 1963, p. 1782, 1783.

Consideration of the fact that laser action should be obtainable in many of the indirect gap semiconductors, such as Ge, Si, and GaP, and improved in the direct-gap ones, if it is possible to supply them with a pair of heterojunction injectors. These should consist of heavily doped semiconductor layers with a higher energy gap than the radiating semiconductor, and, ideally, should be of opposite polarity. This proposal is based on the assumption that at sufficiently high carrier injection levels laser action could occur.

A64-12512

POPULATION INVERSION BETWEEN BOUND AND REPULSIVE MOLECULAR ELECTRONIC STATES BY TWO-TEMPERATURE EQUILIBRIUM.

D. A. Leonard, J. C. Keck (Avco Corp., Avco-Everett Research Laboratory, Everett, Mass.), and M. M. Litvak (Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.).

IEEE, Proceedings, vol. 51, Dec. 1963, p. 1785, 1786.

Contract No. AF 04(694)-33.

Proposal of a new class of gas laser systems well suited for high-power operation, in which the upper energy level of the laser transition is predominantly populated by direct electron impact at the electron temperature, and the lower energy level of the laser transition is controlled by collisions between gas atoms at the heavy particle temperature. An example of such a system for direct two-temperature operation is a molecule that has an upper bound electronic state and a lower repulsive electronic state. The criterion for inversion is that the electron temperature be made sufficiently greater than the gas temperature.

A64-12517

STIMULATED EMISSION IN $\text{CaF}_2:\text{Er}^{3+}$.

S. A. Pollack (Space Technology Laboratories, Redondo Beach, Calif.).

IEEE, Proceedings, vol. 51, Dec. 1963, p. 1793, 1794.

Experimental investigation in which optical maser action was observed in $\text{CaF}_2:\text{Er}^{3+}$ at temperatures close to that of liquid nitrogen, with an input energy of about 1000 joule. Determination of the wavelength of stimulated emission is discussed, and a schematic energy level diagram is presented and analyzed showing the laser transition and the principal pumping bands.

A64-12581

GASEOUS LASERS [LASERS A GAZ].

P. Laurès (Compagnie Générale de Télégraphie sans Fil, Centre de Physique Electronique et Corpusculaire, Paris, France).

Annales de Radioélectricité, vol. 18, Jan. 1963, p. 15-48. 57 refs. In French.

Discussion of the possibility of using gaseous and metallic vapors in lasers in order to produce extremely sharp lines and continuous operation. After a brief review of the characteristics of simulated and induced emission, conditions for the operation of a laser are established, and the width of the line produced is determined. Different parameters associated with this oscillation

are then examined, including lifetime of the excited states, and methods of enriching a particular state. It is shown that all these elements make it possible to predict, by means of the conventional systems of masers with two, three, or four levels, certain types of operations by enriching the upper level by means of the second class collisions. The required enriching factors and the available power are calculated.

A64-13040

BIBLIOGRAPHY OF THE OPEN LITERATURE ON LASERS. II. Edward V. Ashburn (Naval Ordnance Test Station, China Lake, Calif.), Bela A. Lengyel (Hughes Aircraft Co., Research Laboratories, Malibu, Calif.), and Raymond W. Merry (Lockheed Aircraft Corp., Lockheed-California Co., Burbank, Calif.). Optical Society of America, Journal, vol. 54, Jan. 1964, p. 135-142.

Bibliography on lasers confined to material in the open scientific literature, not including abstracts of conference papers. Included are only a few of the vast number of expository and review articles that appeared in print. The field of lasers is subdivided into many topics and categories which are assigned identification numbers patterned after the Dewey decimal system. These numbers are printed following each publication whenever the publication contains relevant information of the proper category. The categories can be ascertained by consulting the classification list which follows the list of publications. In this list the categories are arranged numerically, and, following each category, the serial number of every pertinent publication appears.

A64-13201

ARGON TUBE PUMPED LASER.

Leslie T. Long and Robert L. Conger (U.S. Naval Ordnance Laboratory, Corona, Calif.).

Applied Optics, vol. 3, Jan. 1964, p. 156.

Experimental investigation which demonstrates that gas discharge tubes filled with argon gas are at least as effective as xenon discharge tubes for pumping a ruby laser. For the experiment, two U-shaped tubes were placed beside a sapphire overcoated ruby rod. The two tubes and the ruby were wrapped with aluminum foil. It was found that, when the U-shaped discharge tubes contained argon, the laser threshold was the same as when the tubes were filled with xenon. The output of the ruby laser as observed by a phototube and oscilloscope appeared the same with either xenon or argon.

A64-13286

COHERENCE AND TIME SCANNING OF THE EMISSION SPECTRA OF A RUBY LASER.

V. V. Korobkin and A. M. Leontovich (Academy of Sciences, Physics Institute, Moscow, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 44, June 1963, p. 1847-1851.)

Soviet Physics - JETP, vol. 17, Dec. 1963, p. 1242-1245. Translation. 10 refs.

Experimental investigation of the coherence of ruby laser radiation over the entire end surface, in order to explicate the nature of the time dependence of the excitation of these modes. The spectra and beam divergence in separate pulses were studied at -165°C . The radiation coherence was investigated by observing the interference of the radiation with a Michelson interferometer that had one of its mirrors replaced by a prism. Time scanning of the generated radiation was carried out with a type SFR fast camera operating as a photorecorder. The scanning shows that, in the individual bursts, generation occurs in several modes having different axial characteristics. The emission of excited modes is not propagated in a single direction as it would be in a plane-parallel resonator, but in a certain set of directions with a total divergence of 30 to 40° .

A64-13287

OPERATION OF A FOUR-LEVEL OPTICAL QUANTUM GENERATOR.

Iu. A. Anan'ev, V. F. Egorova, A. A. Mak, D. S. Prilezhaev, and B. M. Sedov (State Optical Institute, Leningrad, USSR). (Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 44, June 1963, p. 1884-1888.)

Soviet Physics - JETP, vol. 17, Dec. 1963, p. 1268-1270. Translation.

Theoretical and experimental investigation of the effect, on the properties of an optical quantum generator (laser), of the working substance, the parameters of the resonator, and the pump intensity, based on the steady-state theory of a four-level laser. An equation is developed which shows that the optimum value for transmission depends on the loss in the crystal and on the pump power. In order to check this, the dependence of threshold power and generated power in $\text{CaF}_2:\text{U}^{+3}$ and $\text{CaF}_2:\text{Sm}^{+2}$ lasers on the crystal temperature and the reflection coefficient of the resonator mirror was investigated, as was the dependence of the generated power on the pumping power. The experiments were carried out on cylindrically-shaped crystals whose end surfaces were covered with a dielectric reflecting layer. The results of the experiments show that the elementary theory of steady-state generation developed, satisfactorily describes the principal features of a four-level laser.

A64-13294

THE EFFECTS OF A LASER BEAM IN A LIQUID.

G. A. Askar'ian, A. M. Prokhorov, G. F. Chanturiia, and G. P. Shipulo (Academy of Sciences, Physics Institute, Moscow, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 44, June 1963, p. 2180-2182.)

Soviet Physics - JETP, vol. 17, Dec. 1963, p. 1463-1465. Translation.

Experimental investigation of effervescence, scattering, and photo-hydraulic effects in liquids produced by a laser beam. Experiments are described concerning the effervescence of transparent and absorbing liquids in the intense beam of a ruby laser with a pulse length of about $1 \mu\text{sec}$. Effects arising from focusing the light close to or on the surface of a buoy immersed in the liquid were also studied. It is seen that the effects considered can increase many-fold the amplitude of the pressure waves created in a liquid by a light beam incident on its surface. The amplitude even of the non-shock waves of compression during boiling is determined by the vapor pressure of the liquid at the temperature of local heating and can exceed by a million times the direct light pressure. The subsequent expansion waves can intensify the boiling and breakdown of the liquid.

A64-13340

FREQUENCY TUNING OF GaAs LASER DIODE BY UNIAXIAL STRESS.

Dietrich Meyerhofer and Rubin Braunstein (Radio Corporation of America, RCA Laboratories, Princeton, N. J.).

Applied Physics Letters, vol. 3, Nov. 15, 1963, p. 171, 172.

Experimental investigation of the effect of uniaxial compression on incoherent emission of a GaAs injection laser diode, in order to eliminate the effects of cavity changes during frequency tuning. Three diodes are used, each of which was made by solution growth, but with different amounts of doping. One diode exhibits the predicted linear variation of frequency with stress. The coefficient is in agreement with the calculated value for band-to-band transitions, and consistent with hydrostatic pressure results. In contrast, the behavior of the other diodes cannot be explained by a simple model. The emission appears to take place between energy levels that are more complicated.

A64-13342

SUM FREQUENCIES AND HARMONIC GENERATION IN GaAs LASERS.

M. Garfinkel and W. E. Engeler (General Electric Co., Research Laboratory, Schenectady, N. Y.).

Applied Physics Letters, vol. 3, Nov. 15, 1963, p. 178-180.

Description of experiments of optical mixing within GaAs laser junctions that generate all possible sum frequencies, as well as the harmonics observed by Armstrong. The diodes were mounted in a special header to run continuously at high power levels. At 20°K fundamental powers ranged up to 3.1 w. Detailed spectral

measurements of the diode output were made with a grating spectrometer whose resolution was 40,000. The relative magnitudes of the sum of the harmonic modes, calculated from the measured fundamental mode amplitudes, were in excellent agreement with the observed harmonic spectra. An equation is developed, and experimentally substantiated, which shows that the harmonic power varies as the square of the fundamental power.

A64-13343

LASER-STIMULATED RAMAN EFFECT AND RESONANT FOUR-PHOTON INTERACTIONS IN GASES H_2 , D_2 , and CH_4 .

R. W. Minck, R. W. Terhune, and W. G. Rado (Ford Motor Co., Scientific Laboratory, Dearborn, Mich.).

Applied Physics Letters, vol. 3, Nov. 15, 1963, p. 181-184. 11 refs.

Experimental investigation during which the output of a giant-pulse ruby laser was focused into a cell containing either H_2 , D_2 , or CH_4 , in order to study stimulated Raman scattering and the accompanying creation of radiation at other frequencies through resonant four-photon processes. In all cases the spectra appear as if a diffusion of energy by discrete steps in frequency space had occurred. Stimulated Raman and related effects resonant in the frequency differences between waves are explicated by extending Armstrong's theoretical analysis of nonlinear interactions in lossless media by introducing a finite linewidth for the molecular resonances.

A64-13347

STIMULATED EMISSION OF STOKES AND ANTI-STOKES RAMAN LINES FROM DIAMOND, CALCITE, AND α -SULFUR SINGLE CRYSTALS.

Gisela Eckhardt (Hughes Aircraft Co., Research Laboratories, Malibu, Calif.), D. P. Bortfeld, and M. Geller (Hughes Aircraft Co., Aerospace Group, Culver City, Calif.).

Applied Physics Letters, vol. 3, Oct. 15, 1963, p. 137, 138. 15 refs.

Experimental investigation in which Stokes and anti-Stokes frequency shifts are observed from single crystals placed in a focused beam external to the cavity of a giant-pulse ruby laser. The materials used are diamond, calcite (rhombohedral), and α -sulfur (orthorhombic). The results are tabulated, showing a comparison of the frequency shifts of observed laser lines with Raman-spectroscopic data from the literature. The expected Raman lines of the three crystals were found in the form of single or multiple Stokes lines and single anti-Stokes lines. The intensity of these lines, together with the existence of multiple Stokes lines, indicates stimulated Raman scattering.

A64-13350

INFRARED InSb LASER DIODE IN HIGH MAGNETIC FIELDS.

R. J. Phelan, A. R. Calawa, R. H. Rediker, R. J. Keyes, and B. Lax (Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.).

Applied Physics Letters, vol. 3, Nov. 1, 1963, p. 143-145. 15 refs. USAF-supported research.

Experimental investigation in which the wavelength region of semiconductor lasers was extended to 5.2μ by the development of the InSb diode laser that utilizes high magnetic fields parallel to the current at liquid helium temperatures. Diodes were fabricated from a tellurium-doped single crystal of InSb with an impurity concentration of 7 to $9 \times 10^{15}/\text{cm}^3$, and a Hall mobility in excess of $1 \times 10^5 \text{ cm}^2/\text{volt-sec}$ at 78°K . Preliminary experiments at low magnetic fields indicated that magnetic fields transverse to the flow of current enhanced the spontaneous radiation up to a field of about 2 kgauss, but, with a further increase in the field, the radiation decreased. However, longitudinal magnetic fields continued to increase the photon intensity up to 90 kgauss.

A64-13351

ZEEMAN TUNING AND INTERNAL MODULATION OF THE $\text{CaF}_2:\text{Dy}^{2+}$ LASER.

Zolton J. Kiss (Radio Corporation of America, RCA Laboratories, Princeton, N. J.).

Applied Physics Letters, vol. 3, Nov. 1, 1963, p. 145-148.

Description of the Zeeman tuning of the $\text{CaF}_2:\text{Dy}^{2+}$ laser over a range of 150 Gc, using small homogeneous and inhomogeneous magnetic fields. The fluorescence and laser output of the system were studied with a Jarrell-Ash 3.5-m spectrometer. The results of the Zeeman tuning suggest internal modulation schemes using homogeneous magnetic fields. Such modulation was experimentally demonstrated with a sinusoidally varying magnetic field having a peak amplitude of 80 gauss, using a $\text{CaF}_2:\text{Dy}^{2+}$ laser with its interferometer axis along the [100] crystal direction operated continuously at 27°K in an elliptical pumping arrangement.

A64-13354

THE EFFECT OF UNIAXIAL STRAIN ON THE THRESHOLD CURRENT AND OUTPUT OF GaAs LASERS.

F. M. Ryan and R. C. Miller (Westinghouse Electric Corp., Research Laboratories, Pittsburgh, Pa.).

Applied Physics Letters, vol. 3, Nov. 1, 1963, p. 162, 163.

Experimental investigation of the effects of uniaxial strain on GaAs laser diodes, in order to construct a readily tunable laser. The diodes were prepared by diffusing Zn in GaAs with $10^{18} \text{ Te atoms/cm}^3$. The diodes were placed in an apparatus that allowed forces to be applied perpendicular to Kovar plates while the diode was maintained at 77°K . When the diode was operated as a laser, the output jumped from one mode to another as the pressure was increased, in a fashion similar to that observed with hydrostatic pressure. The laser threshold current always decreased upon the application of uniaxial pressure, which is explained by assuming that the application of a uniaxial strain normal to the plane of the junction increases the probability of spontaneous emission of photons in a direction parallel to the plane of the junction and decreases the probability in the direction perpendicular to the junction.

A64-13355

MULTIMODE OSCILLATION OF THE RUBY LASER NEAR THRESHOLD.

Milton Birnbaum and Tom L. Stocker (Aerospace Corp., El Segundo, Calif.).

Applied Physics Letters, vol. 3, Nov. 1, 1963, p. 164-166. Contract No. AF 04(695)-169.

Experimental investigation which lends strong support to the hypothesis that multimode operation of ruby and other solid-state lasers is due to the nonuniform spatial distribution of the excited ions, which provides a nonlinear coupling between the various modes. A 7.5-cm long and 0.63-mm-diam. ruby rod with Cr^{+3} concentration of 0.04%, 0-degree orientation, and ends flat to quarter-wave and parallel to 6 sec of arc, was employed. The ruby was operated at room temperature about 1 to 3% above threshold with an elliptical cylinder reflector. Beats are observed at 1.1, 2.2, 3.3, 4.4, and 5.5 Gc, in good agreement with the theoretical estimates.

A64-13363

EXCITATION MECHANISMS AND CURRENT DEPENDENCE OF POPULATION INVERSION IN He-Ne LASERS.

A. D. White and E. I. Gordon (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Applied Physics Letters, vol. 3, Dec. 1, 1963, p. 197-199.

Consideration of the results of spectral measurements of the spontaneous light intensity emitted from dc-excited He-Ne gas laser tubes, as a function of discharge current. These measurements, in conjunction with measurements of the He metastable density, were used to explicate the role played by various discharge mechanisms in the creation of inverted populations in the He-Ne system. The spectral intensity measurements consisted in plotting on an x-y recorder the current and radial dependence of the Ne and He emission lines observed from the end and side of a short discharge tube, with a Jarrell-Ash 1/2-m Ebert Monochromator.

A64-13364

SIMILARITY LAWS FOR THE EFFECTS OF PRESSURE AND DISCHARGE DIAMETER ON GAIN OF He-Ne LASERS.

E. I. Gordon and A. D. White (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Applied Physics Letters, vol. 3, Dec. 1, 1963, p. 199-201.

Consideration of the basic excitation mechanisms leading to inversion in the He-Ne gas laser operating at 6328 \AA and 3.39μ , in order to predict the behavior of the medium with changes in the diameter of cylindrical discharge tubes with circular cross sections. Similarity laws are considered for the behavior of the medium with respect to gain, discharge voltage, optimum discharge, and current (electron density).

A64-13365

RUBY LASER GIANT-PULSE GENERATION BY GAIN-SWITCHING.
E. R. Peressini (Aerospace Corp., El Segundo, Calif.).
Applied Physics Letters, vol. 3, Dec. 1, 1963, p. 203-205.
Contract No. AF 04(695)-269.

Description of a method for generating ruby laser giant-pulses without using polarizers or external reflectors. The nonlinear dependence of the threshold pump energy on crystal length is exploited as the controlling parameter. The gain-switching scheme, which switches additional gain into the circuit, operates by switching two 90-degree rods, each of which is too short to oscillate independently, together to form a long rod in which threshold can be reached. The quantitative dependence of the pump energy on crystal length is analyzed to show that this objective can be attained. Briefly described is a giant-pulse apparatus constructed with two 7.5-cm Kemlite Z3H2O flash tubes used in elliptical cylinder configurations.

A64-13367

ION ENERGIES PRODUCED BY LASER GIANT PULSE.
William I. Linlor (Hughes Aircraft Co., Research Laboratories, Malibu, Calif.).
Applied Physics Letters, vol. 3, Dec. 1, 1963, p. 210, 211.

Description of the production of ion energies of about 1,000 ev by the action of a single giant pulse from a ruby laser. The delivered energy was about 0.2 joule in a pulse having full width at half maximum of about 40 nanosec. The peak power was 5.4 Mw. Energy was determined by the time of flight of the ions over a path of 4.3 cm, and ranged from 0.5 μ sec for carbon to 1.2 μ sec for lead. The targets were in a system of 10^{-6} torr. Targets used include C, Al, Au, and Ti plasmas. The most successful experiments were with targets of aluminum and gold foils, the thicknesses of which respectively were 1.8×10^{-4} and 1.6×10^{-4} gm/cm². It is found that the ion energy measured by a fore collector is very nearly the same whether a single foil or a thick sheet is the target. After the laser burst, the single foil required about 0.3 μ sec for the heat to penetrate the full foil thickness.

A64-13368

DEPENDENCE OF POWER OUTPUT OF A GAS LASER ON THE LENGTH AND RATE OF EXCITATION OF THE DISCHARGE.
J. A. White (National Bureau of Standards, Washington, D. C.).
Applied Physics Letters, vol. 3, Oct. 1, 1963, p. 107-109.

Analytic investigation of the characteristic features of the gas laser output to be expected when the frequencies of oscillation are sufficiently far apart that interactions between the different modes can be neglected. It is assumed that the resonant frequencies of these modes are all displaced from the atomic frequency by at least a natural atomic linewidth, so that only those atoms moving fast enough along the axis of the cavity for there to be a Doppler shift of this magnitude will interact appreciably with the radiation. It is shown that the number of photons in an isolated mode increases high above threshold as the square of the rate of excitation. The results are compared to those of White, Gordon, and Rigden.

A64-13371

REVERSE PHOTOELECTRIC EFFECT AND POSITIVE ION EMISSION CAUSED BY Nd-IN-GLASS LASER RADIATION.
David Lichtman and J. F. Ready (Honeywell Research Center, Hopkins, Minn.).

Applied Physics Letters, vol. 3, Oct. 1, 1963, p. 115, 116.

Brief description of a reverse photoelectric effect caused by photons emitted from a heated target illuminated by laser radiation.

The target materials were tungsten and "Dag"-coated metal. Two different types of spikes are apparent in the output - sharp spikes of current synchronous with the laser spikes, and broader peaks of current with smaller amplitude, that are delayed relative to the laser spikes. The sharp spikes are interpreted as the reverse photoelectric effect, and the broader spikes as positive ion collection.

A64-13372

STIMULATED EMISSION IN RARE-EARTH CHELATE (EUROPIUM BENZOYLACETONATE) IN A CAPILLARY TUBE.

Erhard J. Schimitschek (U. S. Navy, Electronics Laboratory, San Diego, Calif.).

Applied Physics Letters, vol. 3, Oct. 1, 1963, p. 117, 118.

Experimental investigation of the conditions for laser action in europium benzoylacetate (EuB), using a 10^{-2} -molar alcoholic solution prepared with piperidine and contained in a capillary quartz tube .08 cm in diameter and 5 cm long. Nearly confocal, movable mirrors in contact with the liquid provided the necessary feedback and prevented the formation of bubbles in the laser path when cooled to low temperatures. Laser action was achieved with dielectric as well as silver coatings on the mirrors.

A64-13373

PLASMA REFRACTIVE INDEX BY A LASER PHASE MEASUREMENT.
J. B. Gerardo and J. T. Verdeyen (Illinois, University, Urbana, Ill.).

Applied Physics Letters, vol. 3, Oct. 1, 1963, p. 121-123.
Contract No. SC 87232.

Description of a technique for using lasers as a source for interferometers employed in plasma diagnostics. The output from one end of a laser is sent through a plasma and reflected back onto itself by a spherical mirror. If the plasma density changes with time, a sequence of resonances at the laser frequency will be excited in the laser cavity. Since the phase of the signal fed back to the laser depends on the proximity to resonance, the laser output will vary, attaining an extreme value each time when the cavity is swept through a resonance. Typical experimental results are presented which clearly show the amplitude variation of the laser output.

A64-13432

ELECTRONIC AND MUTUAL COMPONENTS OF STIMULATED EMISSION IN LASERS.

G. F. Lewin (Brunel College, Physics Dept., London, England).
Journal of Electronics and Control, First Series, vol. 16, Jan. 1964, p. 21-28. 10 refs.

Evaluation of the perturbation energy between the magnetic field of incident electromagnetic radiation and a laser electron. It is shown that the energy is small. A wave-mechanical treatment of laser action is given for the electric field perturbation, and, from this, an expression is obtained for the emission or negative absorption coefficient which is in agreement with the calculation of Karplus and Schwinger (1948), based on matrix mechanics. Evaluation of this component for the $n = 2, l = 1, m = 0$, and $n = 3, l = 0, m = 0$ levels of a hydrogen-like atom leads to a simple relation between emission coefficient and wavelength. The emission coefficient is inversely proportional to wavelength, bandwidth, and the atomic number squared, for given initial numbers of atoms in the two levels.

A64-13434

LASER INDUCED ELECTRON EMISSION FROM TUNGSTEN POINTS.

A. J. Alcock, M. Iannuzzi, H. Motz, and D. Walsh (Oxford University, Engineering Laboratory, Oxford, England).

Journal of Electronics and Control, First Series, vol. 16, Jan. 1964, p. 75-77.

USAF-supported research.

Observations of laser induced emission from a tungsten point that appears to have two distinct ranges of rise and decay time. Described is the experimental arrangement used, which enabled emission rise and decay times of order 10^{-7} sec to be observed. Reproduced in a figure is a trace showing the emission which occurs several tens of microseconds after the laser oscillations commence. The resulting current pulses appear to be thermionic in character, the peaks being delayed by a fraction of a microsecond, and the decay time constant being around 2-3 microseconds. In this case the input energy to the flashtube was 64% above the laser threshold. The following is pointed out: (1) although some traces show a delay consistent with Ready's calculations, others show extremely fast recovery, and the emission follows the laser pulses almost faithfully; (2) the emission seems to miss some laser pulses. This might occur for modes which do not focus on the point.

A64-13489

LASERS - A NEW TECHNOLOGY.

Ellery P. Snyder (Perkin-Elmer Corp., Norwalk, Conn.).
Space Dimensions, vol. 1, Oct. 1963, p. 10-13.

Discussion of laser characteristics which make them suitable for air navigation and flight safety applications. Uses of the coherent, narrow-beam, monochromatic, high energy-density, plane polarized laser beams for navigation, communications, surveillance, altitude measurement, and collision avoidance are noted. Briefly considered is a precision CW optical radar system, PIRT, which has been designed for the determination of missile trajectories. The system is similar to a radar, with the laser replacing high-powered RF amplifiers and the optical systems replacing radar antennas. A TV camera and other subsidiary optical systems are used for target acquisition.

A64-13528

QUANTUM-THEORETICAL COMPARISON OF NONLINEAR SUSCEPTIBILITIES IN PARAMETRIC MEDIA, LASERS, AND RAMAN LASERS. N. Bloembergen and Y. R. Shen (Harvard University, Dept. of Engineering and Applied Physics, Cambridge, Mass.).
Physical Review, 2nd Series, vol. 133, Jan. 6, 1964, p. 37-49. 36 refs. Navy-Army-USAF-ARPA-supported research.

Description, by the density matrix method, of the steady-state response of a nonlinear medium to several simultaneously applied monochromatic electromagnetic fields. A Fourier series expansion in terms of ascending powers of the amplitudes of the applied fields is especially useful to describe the parametric response in spectral regions, where the absorption is small. As the resonances of the material system are approached, the general formalism exhibits the mixture and interference between parametric processes and single- and multiple-photon absorption and emission processes. Previously discussed examples of the two-level and three-level system are generalized. The reaction of the general nonlinear medium on the electromagnetic fields is incorporated. It is noted that joint equations of the dynamical variables of the modes and the density matrix elements of the general nonlinear medium can be written down, although explicit steady-state solutions require the retention of only a few terms in a Fourier series expansion, truncation of nonresonant terms, and other approximations.

A64-13531

INTERACTION OF OPTICAL AND INFRARED RADIATION WITH METASTABLE HYDROGEN ATOMS. Wolfgang Zernik (Radio Corporation of America, Plasma and Space Applied Physics, Princeton, N. J.).
Physical Review, 2nd Series, vol. 133, Jan. 6, 1964, p. 117-120.

Discussion of the theory of the quenching of the metastable 2S state of atomic hydrogen by means of optical radiation, for example, by the light from a ruby laser. The case discussed is that for which the incident intensity is sufficiently weak for the usual quantum-electrodynamical perturbation theory to be valid. A procedure developed by Schwartz and others is used to carry out the sum over intermediate states without explicit enumeration. The results are given for a range of incident wavelengths from 5000 \AA to 50μ . For unpolarized light from a ruby laser (6934 \AA), the total cross section for quenching is found to be $\delta_Q = 1.27 \times 10^{-22} \text{ cm}^2$. The cross section

for coherent scattering has also been calculated for the same range of wavelengths; for ruby laser light, the total cross section for scattering is found to be $\delta_s = 1.03 \times 10^{-23} \text{ cm}^2$.

A64-13593

DESIGNING LASERS WITH PUMP-POWER CHARTS.

Robert A. Kaplan (Wheeler Laboratories, Great Neck, N. Y.).
Electronics, vol. 36, Dec. 27, 1963, p. 23-28.

Description of a graphical method, using pump-power charts, which relates pump power, wavelength, and propagation direction of a laser. As a first step, the modes of the resonator are plotted on a mode chart in terms of the direction of propagation and of the resonant wavelength of the plane waves comprising those modes. The relations between threshold pump power and these factors appear as contours on the chart, forming the pump-power chart. This chart permits the determination of laser oscillation modes at a given pump level in terms of wavelength and direction of propagation, and, thereby, permits the determination of the frequency and angular spectra of the emitted radiation. In particular, the total bandwidth of the laser output may be obtained directly.

A64-13637

ULTRAHIGH-SPEED PHOTOGRAPHY.

Kenneth R. Coleman (Atomic Weapons Research Establishment, Harwell, Berks., England).

International Science and Technology, Jan. 1964, p. 40-44, 47, 50, 51.

Discussion of ultrahigh-speed photography, in which exposure times range from less than 50 microseconds to as short as a few nanoseconds. High-speed phenomena such as flow in chemical plants, the dynamics of stress-strain, and the rotation of a pinch of plasma, become the camera's targets. It is noted that an object can be lit briefly by extremely bright sparks or high-intensity gas discharges, but the self-illumination of a hot flame requires a laser flash to produce a meaningful photographic record. Records are frames or streaks of data. One of the biggest problems in photography is the investigation of an object surrounded by a medium which scatters for some reason. The best optical solution, so far, brings together several of the techniques of high-speed photography. The light source is a laser; the camera is an image tube because it is sensitive and has an exposure time of the same order as the light pulse.

A64-13663

SIGNAL DETECTION WITH A LASER AMPLIFIER.

Herbert A. Steinberg (Technical Research Group, Inc., Syosset, N. Y.).

IEEE, Proceedings, vol. 52, Jan. 1964, p. 28-32.

Contract No. AF 49(638)-673.

Study of the possible application of a pulsed laser radar, which uses a quantum detector followed by a threshold discriminator, for signal detection. The value of preceding the detector with a laser amplifier is discussed. The analysis shows that, under certain specified conditions, a laser amplifier is a definite asset to the system; under others, its use results in no enhancements, and may even have a degrading effect on system performance. The exact distribution of the input to the threshold discriminator of the noise and of the signal is calculated on the assumption that the lower state population of the amplifier is empty.

A64-13670

EXPERIMENT ON QUASI-FUNDAMENTAL MODE OSCILLATION OF RUBY LASER.

Yasuharu Suematsu and Kenichi Iga (Tokyo Institute of Technology, Tokyo, Japan).

IEEE, Proceedings, vol. 52, Jan. 1964, p. 87, 88.

Measurement of the radiation angles of the output light associated with a ruby rod with dielectric multilayer plane reflectors on the whole area at both ends of the rod. The results are compared with the calculated values using relations between a radiation angle

and the pumping energy of a ruby laser. Transverse fundamental mode oscillations are obtained by restricting the diameter of one of the reflectors within approximately one order smaller than that of the rod.

A64-13671

LASER EMISSION FROM A MOVING RUBY ROD.

J. Free and A. Korpel (Zenith Radio Corp., Chicago, Ill.).
IEEE, Proceedings, vol. 52, Jan. 1964, p. 90.

Study of laser emission from a moving ruby rod by using stationary mirrors and moving the ruby through the standing-wave pattern at such a rate that each point in the ruby passes several standing-wave axial nodes during buildup of individual laser pulses. Typical laser outputs in the absence of movement and at velocities around 0.4 m/sec are graphically illustrated. It is found that the output from a moving ruby rod is far more regular.

A64-13672

SILICON CARBIDE DIODE "LASER."

R. N. Hall (General Electric Co., Research Laboratory, Schenectady, N.Y.).

IEEE, Proceedings, vol. 52, Jan. 1964, p. 91.
Contract No. AF 19(628)-329.

Discussion of the junction luminescence from SiC diodes which has been interpreted as evidence for stimulated emission and for the generation of coherent light. It is pointed out that: (1) the evidence for coherence and stimulated emission is inconclusive; (2) the possibility that stimulated emission is involved in these experiments is ruled out by theoretical considerations; and (3) the data can be explained in terms of the presently known properties of SiC as being due to the spontaneous recombination of bound excitations.

A64-13673

MAGNETIC TUNING OF CW InSb DIODE LASER.

R. J. Phelan, Jr. and R. H. Rediker (Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.).

IEEE, Proceedings, vol. 52, Jan. 1964, p. 91, 92.
USAF-supported research.

Discussion of the operation of forward biased InSb diodes as CW lasers, and of changing the emission wavelength in steps of 50 Å from one cavity mode to an adjacent one by applying incremental steps of magnetic fields of less than 600 gauss. Spectra of CW emission from InSb diode laser at 2°K and 1 a dc forward current are included. It is shown that the emission wavelength is tuned from one cavity mode to an adjacent one by varying the magnetic field by less than 600 gauss.

A64-13674

PROPOSED GEOMETRY FOR OBTAINING A MORE HIGHLY COLLIMATED LIGHT BEAM OF GREATER INTENSITY FROM GaAs LASERS.

Francis Harper (Sandia Corp., Sandia Base, Albuquerque, N.M.).
IEEE, Proceedings, vol. 52, Jan. 1964, p. 92, 93.

Presentation of a method for obtaining the emitted light in one central beam of maximum intensity. It is shown that the proposed slight modification of the geometry of existing GaAs diode lasers will eliminate the undesired modes and should result in a single, more highly collimated and highly polarized central beam of greater intensity. It is also proposed that the elimination of the undesired mode may lead to stimulated emission at a lower threshold.

A64-13675

A HIGH REPETITION RATE LASER SYSTEM.

W. T. Haswell, III, J. S. Hitt, and J. M. Feldman (Carnegie Institute of Technology, Pittsburgh, Pa.).

IEEE, Proceedings, vol. 52, Jan. 1964, p. 93.

Brief description of an ambient-cooled laser system which has been successfully operated at an average output power of thirty watts by the use of an electrodeless discharge in argon. The low

temperature of the discharge tube which dissipates about 3 kw indicates that this type of discharge is considerably more efficient in converting the input energy into optical radiation than the conventional arc discharge lamps.

A64-13677

OPTICALLY-INDUCED ULTRASONIC WAVES IN TRANSPARENT DIELECTRICS.

A. J. DeMaria (United Aircraft Corp., Research Laboratories, East Hartford, Conn.).

IEEE, Proceedings, vol. 52, Jan. 1964, p. 96, 97.

Study of the mechanism involved in the optical generation of elastic waves in transparent dielectrics. The following two hypotheses are postulated to account for the launching of the acoustic disturbances by the laser's pulsating radiant energy: (1) thermal expansion resulting from heating produced by the absorption of the laser's radiant energy, and (2) forces predicted by classical electromagnetic theory which are proportional to the gradient of the field-energy density.

A64-13793

LASER MISSILE TRACKER.

Ellery P. Snyder (Perkin-Elmer Corp., Norwalk, Conn.).

Ordnance, vol. 48, Jan.-Feb. 1964, p. 447, 448.

Brief description of requirements of a modulated-power continuous-wave optical system for tracking the target, measuring elevation and azimuth angles and range, and sending and recording data. It is designed to measure the position of a rocket or missile at very high accuracies from launch to 50,000 ft.

A64-13902

GASEOUS AND CRYSTAL MASERS FOR MICROWAVES [GASFÖRMIGE UND KRISTALLINE MOLEKULARSTRAHLER FÜR MIKROWELLEN].

Emil C. Metschl (Verein Deutscher Ingenieure, Siemens und Halske AG, Wernerwerk für Bauelemente, Munich, Germany).

VDI Zeitschrift, vol. 105, Dec. 1963, p. 1719-1725. 35 refs.
In German.

Consideration of the principles and applications of the generation and amplification of microwaves by means of controlled variations of molecular and atomic energy states in gases and solids. These masers, which are suited to amplify very small power because of the almost entire lack of thermal background noise, are employed in radio telescopes to observe distant radio stars, and in such astronomical equipment as radios for satellite communications.

A64-14048

SHOCK WAVES IN XENON FLASHTUBES AND TUBE DETERIORATION.

Kenneth R. Lang and Frank S. Barnes (Colorado, University, Dept. of Electrical Engineering, Boulder, Colo.).

(American Physical Society, Division of High-Polymer Physics, Meeting, St. Louis, Mo., Mar. 25-28, 1963.)

Journal of Applied Physics, vol. 35, Jan. 1964, p. 107-110.

Research supported by NSF, NBS, and the Minneapolis-Honeywell Co.

Experimental investigation of the shock waves in a xenon flashtube at laser pumping energies, and of their effect on tube deterioration. The plasma discharge was investigated by taking high-speed image converter and streak photographs of the discharges and by measuring the relative shock amplitude at the tube walls with a piezoelectric transducer. The velocity of the luminous boundary of the plasma discharge was proportional to the input energy in the range from 60 to 500 joule and varied from 90 to 900 m/sec. The luminous boundary velocity remained constant for pressures from 100 to 1,500 torr. The relative shock amplitude measured by the electromechanical transducer was independent of the tube diameter up to 12 mm, increased linearly with the input energy, and increased

with gas pressure. Shock data were correlated with efficiency measurements to determine optimum tube and operational parameters. The microscopic effects of the shock wave upon the tube wall indicated that the prestressing in compression of the exterior surfaces of the glass wall would yield a stronger flashtube capable of higher intensities.

A64-14050**MULTIPLE PROBE MEASUREMENTS IN HIGH-FREQUENCY PLASMA LASERS.**

Sol Aisenberg (Raytheon Co., Research Div., Waltham, Mass.). (American Physical Society, Division of High-Polymer Physics, Meeting, St. Louis, Mo., Mar. 25-28, 1963.)

Journal of Applied Physics, vol. 35, Jan. 1964, p. 130-134. 14 refs.

Description of a multiple probe technique for the accurate measurement of the retarding potential characteristics of probes in HF electrodeless plasmas. The assumptions, advantages, and limitations of earlier multiple probe methods are discussed. In the new technique a small probe is used for the actual measurement of the probe current. A large area probe is used to drive the plasma or to anchor the plasma if the current measuring probe itself is driven. In order to reduce the plasma disturbance due to the large driving probe, it is located far from the first probe. A third probe located near the first is used to correct for changes of plasma potential reference. A circuit diagram of the probe method is presented. It is seen that the technique allows the complete probe characteristic to be traced rapidly. From the retarding potential characteristic for the electrons, the electron temperature and density can be determined for the low-energy electrons, together with the electron energy distribution function.

A64-14055**INTERNAL SECOND-HARMONIC GENERATION IN GALLIUM ARSENIDE LASERS.**

L. D. Malmstrom, J. J. Schlickman, and R. H. Kingston (Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.).

(American Physical Society, Division of High-Polymer Physics, Meeting, St. Louis, Mo., Mar. 25-28, 1963.)

Journal of Applied Physics, vol. 35, Jan. 1964, p. 248, 249.

Description of observations of second-harmonic radiation self-induced in a gallium arsenide laser by the intense electric fields at the junction when operating at 0.846μ . The samples were rectangular parallelepipeds approximately 0.5 mm^2 and 2 mm long, with the square faces being cleaved surfaces. The lasers were operated at liquid-nitrogen temperature and yielded peak pulse powers up to 20 watt at 100 amp with a pulse width of 5μ sec and a repetition rate of 13 cps. The nonlinear susceptibility of gallium arsenide is estimated for the second-harmonic process at 0.846μ . It is shown that, if the fundamental electric field distribution is assumed uniform throughout the diode, then the second-harmonic power is dissipated in the ratio of the diode length to the skin depth.

A64-14056**DEPENDENCE OF THE OPTICAL-MASER THRESHOLD ON NEODYMIUM CONCENTRATION IN SODIUM-COMPENSATED CALCIUM TUNGSTATE.**

A. E. Paladino, B. D. Roiter, and G. deMars (Raytheon Co., Research Div., Waltham, Mass.).

(American Physical Society, Division of High-Polymer Physics, Meeting, St. Louis, Mo., Mar. 25-28, 1963.)

Journal of Applied Physics, vol. 35, Jan. 1964, p. 249, 250.

Description of the preparation and evaluation of $\text{CaWO}_4:\text{Nd}$ crystals for application in continuously operating solid-state masers. Samples of the crystals in the form of rods approximately 5 cm long by 2.5 to 3.2 mm in diameter were fabricated to determine the threshold of laser oscillation. The dependence of the threshold on the nominal neodymium concentration is plotted. It is found that the threshold decreases with increasing neodymium concentration up to a point somewhere between one and two per cent.

A64-14088**PROPERTIES OF LASER RESONATORS GIVING UNIPHASE WAVE FRONTS.**

Arnold L. Bloom.

Spectra-Physics Laser Technical Bulletin, no. 2, Aug. 1963. 7 p.

Discussion of the properties of the hemispherical and other resonators designed specifically for production of uniphase wave fronts, and comparison of the advantages and disadvantages of various types that may be used for this purpose. It is noted that, for most applications, the hemispherical resonator is preferred because adjustments for a stable uniphase wave front are easily made, and because angular alignment of mirrors is not critical. Its only disadvantage is a reduction of output power resulting from the fact that only about one-third the volume of a cylindrical tube is filled with the laser mode. For applications requiring the absolute maximum of power, the large-radius mirror configuration is to be preferred, but then the user has no control over the cavity mode dimension and the effects of optical perturbations within the cavity upon the mode. Where high gain requirements dictate a very small tube diameter, the confocal resonator may be used.

A64-14089**OPTICAL PROPERTIES OF LASERS AS COMPARED TO CONVENTIONAL RADIATORS.**

Robert C. Rempel.

Spectra-Physics Laser Technical Bulletin, no. 1, June 1963. 10 p.

Comparison of the properties of coherent laser radiation with those of conventional incoherent radiation in a variety of optical applications. Quantitative calculations are made which show that, in the case of focal plane illumination, the intensity from typical laser radiation is 4 to 5 orders of magnitude greater than the intensity from the most intense incoherent source. When used in coherent optical data processing systems, the laser provides an increase in optical power relative to the incoherent source in the range 2 to 4 orders of magnitude for one-dimensional data processing, and in the range 5 to 9 orders of magnitude for two-dimensional data processing. For interferometric testing of optical surfaces with close spacing, in either the real or image sense, between the surfaces being compared, the mercury arc lamp is shown to have about 25 times greater intensity than the laser. Here the advantage to the laser is that the long coherence eliminates any necessity for compensating plates. It is shown that, in a large number of applications, the use of a laser will yield an increase of many orders of magnitude in useful intensity relative to that obtainable from an incoherent radiator.

A64-14136**EXISTENCE OF EIGENVALUES OF A CLASS OF INTEGRAL EQUATIONS ARISING IN LASER THEORY.**

D. J. Newman (Bell Telephone Laboratories, Inc., Murray Hill, N. J.; Yeshiva University, New York, N. Y.) and S. P. Morgan (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Bell System Technical Journal, vol. 43, Jan. 1964, p. 113-126.

Discussion of proof that it is possible to pick one eigenvalue from a set of eigenvalues in such a way that the resulting sequence of numbers has a nonzero limit point. Details of the argument are given in a series of lemmas. The proof of the main theorem is also given. For a gas laser with finite (not strip) mirrors of arbitrary, dissimilar shape and size, the integral equation still has a complex symmetric kernel, although the domain of integration is two-dimensional and the kernel is more complicated than that of Fox and Li.

A64-14138**MATCHING OF OPTICAL MODES.**

H. Kogelnik.

Bell System Technical Journal, vol. 43, Jan. 1964, p. 334-337.

Experimental study of the light beam from a He-Ne gas laser oscillating in a fundamental mode at $\lambda = 0.63$ micron. Presented are simple matching formulas, and a matching experiment is described for illustration.

A64-14260

EXFOCAL PUMPING OF OPTICAL MASERS IN ELLIPTICAL MIRRORS.

Dieter Roess (Siemens and Halske AG, Central Laboratories, Munich, Germany).

Applied Optics, vol. 3, Feb. 1964, p. 259-265, 11 refs.

Demonstration that an efficiency near unity can be achieved in optical pumping devices for lasers, where unabsorbed light is refocused at the light source, leading to multiple passes of pumping energy through source and laser. In properly dimensioned elliptical mirrors this can, in principle, be done by placing source and laser outside of the focal points. Furthermore, in these "exfocal" elliptical designs the light density of the source is transformed into the laser at a ratio of 1:1, resulting in very low-threshold energies. The lowest value observed for ruby lasers up to 7.6 cm in length was 50 W-sec at room temperature in a rotational-ellipsoidal mirror where the axis of source and laser are oriented in the rotational axis of the ellipsoid, while their lengths are equal to the distance between focus and wall. Alternative designs are exfocal elliptical and circular cylinders. In exfocal ellipsoids the pump light distribution is of exactly rotational symmetry which leads to symmetrical absorption of pumping light in the laser. As a result, quasi-periodic relaxation oscillations of 5000- μ sec duration and a component of continuous emission have been observed at room temperature with 300 W-sec pumping energy.

A64-14271

PULSED LASER BEAM PICTURES.

Raymond Jeanes, Jr. (Tufts University, Medford, Mass.).

Applied Optics, vol. 3, Feb. 1964, p. 318.

AEC-supported research.

Brief description of a quick and accurate method for determining the laser beam size and location using ordinary carbon paper. The method is useful in aligning the laser with bolometers and other devices where the beam must enter an aperture which is approximately the same size as the beam. Other advantages of the method include the ability to take "pictures" without darkening the room, and the small expense involved.

A64-14551

SEMICONDUCTOR LASERS.

T. M. Quist.

International Science and Technology, Feb. 1964, p. 80-86, 88, 114, 116.

Description of the latest version of the semiconductor laser. Its coherent beam can be tailored to any wavelength from the mid-infrared to the visible. The physical principles of semiconductor lasers are the same as in other lasers. However, the device itself is vastly different: it is small, a self-contained unit needing only a current to produce the coherent beam. The amplitude of the beam can be modulated by modulating the current. The semiconductor material is gallium arsenide phosphide, a direct gap material, where by recombination of holes and electrons a photon is emitted. The most important feature of the device is the possibility of generation of an infinite variety of wavelengths by varying the ingredients in the semiconductor.

A64-14797

DESIGN CONSIDERATIONS FOR LASER PULSE AMPLIFIERS.

A. E. Siegman (Stanford University, Stanford Electronics Laboratories, Stanford, Calif.).

Journal of Applied Physics, vol. 35, Feb. 1964, p. 460.

Brief consideration of various alternative forms in which can be written the author's results from a previous study concerning the time varying amplification of a pulse of radiation passing through an idealized laser amplifier, neglecting pumping during the passage of the pulse. One form in which the results are written shows that the gain experienced by an increment of input $P_{in}(t)dt$ arriving at time t depends only on the initial gain and on the integrated input pulse energy up to the time compared to the available energy. Another form is useful because it permits direct calculation of the input pulse shape required to obtain a specified output pulse shape.

A64-14808

ZEEMAN AND COHERENCE EFFECTS IN THE He-Ne LASER.

W. Culshaw and J. Kannelaud (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Research Laboratories, Palo Alto, Calif.). Physical Review, 2nd Series, vol. 133, Feb. 3, 1964, p. A691-A704, 36 refs.

Research supported by the Lockheed Independent Research Program.

Investigation of the influence of the Zeeman effect upon He-Ne laser transition at $\lambda = 1.153 \mu$, using both planar- and confocal-type resonators. For Zeeman level separations larger than the natural line widths, the specific polarizations of the Zeeman transitions for the appropriate geometry are observed in the planar laser. Low-frequency splittings of axial resonances are found to occur, which are associated with anomalous dispersion effects, and the polarization of which is either linear, circular, or orthogonal. At magnetic-field values for which the Zeeman levels overlap, coherence effects in the induced radiation are made evident by the disappearance of such low-frequency beats and by changes in these polarizations. These findings are discussed on the basis of the theory of the depolarization of resonance radiation by magnetic fields, as well as of time-dependent perturbation methods. For a symmetrical location of the axial resonance within the Doppler-broadened line, linear polarization is predicted for axial magnetic fields for which the states overlap. Some experimental verification is presented. Related effects are found to occur in the confocal laser, where the Brewster angle windows determine the polarization.

A64-14809

INTERACTION OF INTENSE LASER BEAMS WITH ELECTRONS.

Lowell S. Brown and T. W. B. Kibble (London, University, Imperial College of Science and Technology, Dept. of Physics, London, England).

Physical Review, 2nd Series, vol. 133, Feb. 3, 1964, p. A705-A719, 18 refs.

USAF-supported research.

Discussion of the interaction of an intense coherent photon beam with free electrons, treating the photon beam as a classical external electromagnetic field. The analysis is exact within the approximation of neglecting radiative corrections. It is limited to the case of a plane-wave field of arbitrary spectral composition and polarization properties. The scattering of a single photon out of a monochromatic beam by an isolated free electron is examined in detail, and the cross sections corresponding to the scattering of the various harmonics of the incident beam are evaluated. The cross sections display a complicated dependence upon the intensity of the incident beam. Other processes involving free electrons in the final state are treated briefly, and the magnitude of the effects is evaluated as a function of intensity. The electron Green's function and the vacuum-vacuum transformation function, in the presence of a magnetic field, are discussed in appendices.

A64-14926

CUTOFF FREQUENCIES OF THE DIELECTRICALLY LOADED COMB STRUCTURE AS USED IN TRAVELING-WAVE MASERS.

S. E. Harris, E. O. Schulz-DuBois (Bell Telephone Laboratories, Inc., Murray Hill, N.J.), and R. W. DeGrasse (Microwave Electronics Corp., Palo Alto, Calif.).

Bell System Technical Journal, vol. 43, Jan. 1964, p. 437-484, 7 refs.

Contract No. DA 36-039-sc-85357.

Review of the subject of traveling-wave maser design and outline of an analytical design procedure. A method is derived for calculating the upper and lower cutoff frequencies of a comb-type slow-wave structure of simple geometry. It is based on the electromagnetic field pattern and the equivalent impedances which are calculated for these frequencies, both for the dielectrically loaded and the empty comb structure. The design procedure resulting from these calculations permits the prediction of a dielectric loading geometry that shifts the upper and lower cutoff frequency of the empty comb to new, lower values which can be arbitrarily specified within certain limitations. Frequencies calculated by this procedure are compared with the results of measurements, and it is found that cutoff frequencies can be predicted to better than 10%.

A64-14927

OPTICAL MASER OSCILLATORS AND NOISE.

Eugene I. Gordon (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

Bell System Technical Journal, vol. 43, Jan. 1964, p. 507-539. 22 refs.

Extension of the transmission line matrix formalism useful for describing the transfer properties of microwave networks to the electromagnetic fields associated with optical masers. The spontaneous emission noise of the optical maser is examined and shown to be amenable to a thermal description. Taking the point of view, well accepted at microwave frequencies, that a weakly nonlinear oscillator is a saturated amplifier of noise, the power and linewidth of the noise radiation emitted by the optical maser are calculated using the transmission line formalism. The significant parameters for any optical maser are shown to be the frequency, the single-pass gain of the maser medium, the effective mirror reflectivity and the population ratio. The pre-oscillation characteristics of the maser are examined and the reason for the extremely sharp oscillation threshold of the gas masers is discussed. Some observations concerning semiconductor optical masers are also made.

A64-14939

CONSIDERATIONS OF NOISE AND SCHEMES FOR ITS REDUCTION IN LASER AMPLIFIERS.

H. Kogelnik (Bell Telephone Laboratories, Inc., Murray Hill, N.J.) and A. Yariv (Watkins-Johnson Co., Palo Alto, Calif.).

IEEE, Proceedings, vol. 52, Feb. 1964, p. 165-172. 12 refs.

Discussion of the radiation characteristics of noise added by spontaneous emission to the signal in laser amplifiers. Structures that can reduce this noise are considered. These structures make use of the spatial directionality of coherent light, and consist of aperture stops in combination with lenses. Their ultimate performance is studied. Signal-beam configurations necessary for optimum signal-to-noise ratio are described.

A64-14943

ELECTRO-OPTIC LIGHT BEAM DEFLECTOR.

V. J. Fowler, C. F. Buhner, and L. R. Bloom (General Telephone and Electronics Laboratories, Inc., Bayside, N.Y.).

IEEE, Proceedings, vol. 52, Feb. 1964, p. 193, 194.

Development of a method for producing rapid deflection of light beams by purely electrical means. The method was laboratory tested and found to be applicable to a precision high-deflection-rate scanner for use in the acquisition and tracking of laser beams in optical communication and navigation systems. Deflection is accomplished by passing a light beam through a refracting medium, in which an electric field induces a linear variation in the index of refraction in a direction transverse to the direction of propagation of the light beam. For small changes in the refractive index and short enough path lengths, the light travels through the structure in nearly horizontal lines.

A64-14946

AMMONIA MASER WITH SEPARATED OSCILLATING FIELDS.

Stephen G. Kukolich (Massachusetts Institute of Technology, Research Laboratory of Electronics and Dept. of Physics, Cambridge, Mass.).

IEEE, Proceedings, vol. 52, Feb. 1964, p. 211. 7 refs.

Army-USAF-Navy-supported research.

Observation of the 3-2 inversion transition in ammonia by means of a molecular beam maser with two microwave cavities separated by 36 cm. The resulting resonance shows the typical Ramsay shape with several peaks, the width of these peaks being determined by the separation of the microwave cavities. This device is similar to the original ammonia maser in physical construction but differs in two respects: this device does not oscillate spontaneously; and the linewidth is much narrower, since it depends on the separation of the microwave cavities. Microwave power is injected into the first cavity, and a microwave receiver is connected to the second cavity. Both cavities have open ends so that some of the microwave power from the first cavity is coupled into the second cavity. The conditions are similar to those described by Ramsey for resonance with separated oscillating fields, except that here the transition probability is not measured by deflection of the beam but by observing the additional power delivered to the microwave receiver by the ammonia molecules.

A64-14949

DETECTION OF THE TRANSVERSE DOPPLER EFFECT WITH LASER LIGHT.

Reinhold Gerharz.

IEEE, Proceedings, vol. 52, Feb. 1964, p. 218.

Brief consideration of the theoretical principles for testing the theory of relativity with the relativistic (transverse) Doppler effect by means of satellite communication and orbital element determination employing laser techniques. The theory involves the application of a Lorentz transformation for obtaining a time correlation of two systems of reference: one being that of the light source in motion, the other being that of the observer. It is noted that a factor of two in the transverse Doppler shift can be gained if the satellite is equipped with directional mirrors which reflect the light back to the location of the emitter.

A64-14959

TEST OF SPECIAL RELATIVITY OR OF THE ISOTROPY OF SPACE BY USE OF INFRARED MASERS.

T. S. Jaseja, A. Javan, J. Murray, and C. H. Townes (Massachusetts Institute of Technology, Cambridge, Mass.).

Physical Review, 2nd Series, vol. 133, Mar. 2, 1964, p. A1221-A1225. 11 refs.

Research supported by NASA and a Tri-Service Contract in the Research Laboratory of Electronics.

The highly monochromatic frequencies of optical or infrared masers allow very sensitive detection of any change in the round-trip optical distance between two reflecting surfaces. Hence, comparison of the frequencies of two masers with axes perpendicular to each other allows an improved experiment of the Michelson-Morley type, or a very precise examination of the isotropy of space with respect to light propagation. Two He-Ne masers were mounted with axes perpendicular on a rotating table carefully isolated from acoustical vibrations. Their frequency difference was found to be constant to within 30 cps over times as short as about one second, or to one part in 10^{13} of the maser frequency, which is near 3×10^{14} cps. Rotation of the table through 90° produced repeatable variations in the frequency difference of about 275 kc/sec, presumably because of magnetostriction in the Invar spacers due to the Earth's magnetic field. Examination of this variation over six consecutive hours shows that there was no relative variation in the maser frequencies associated with orientation of the Earth in space greater than about 3 kc/sec. Hence there is no anisotropy or effect of either drift larger than 1/1000 of the small fractional term $(v/c)^2$ associated with the Earth's orbital velocity. This preliminary version of the experiment is more precise by a factor of about 3 than previous Michelson-Morley experiments. There is reason to hope that improved versions will allow as much as 2 more orders of magnitude in precision, and that similar techniques will also yield considerably improved precision in an experiment of the Kennedy-Thorndike type.

A64-14968

DYNAMICS OF THE GIANT PULSE LASER.

Lee M. Frantz (Space Technology Laboratories, Inc., Redondo Beach, Calif.).

Applied Optics, vol. 3, Mar. 1964, p. 417-420.

Analytical description of the time-dependent behavior of the radiation buildup in a giant pulse laser, neglecting cavity losses. Expressions are derived for the photon density as a function of time, and for the delay time and the rise time of the radiation pulse. The curve of radiant energy density vs time is plotted for several representative values of the parameters involved.

A64-15046

A NEW METHOD OF LASER LIGHT DOWN-CONVERSION AND AMPLIFICATION INTO MICROWAVES BY PARAMETRIC AMPLIFIER.

S. Saito, K. Kurokawa, J. Fujii, T. Kimura, and K. Uno (Tokyo University, Institute of Industrial Science, Tokyo, Japan).

IN: INTERNATIONAL SYMPOSIUM ON SPACE TECHNOLOGY AND SCIENCE, TOKYO, JAPAN, AUGUST 27-31, 1962, 4th, PROCEEDINGS.

Edited by Tamiya Nomura.

Tokyo, Japan and Rutland, Vt., Japan Publications Trading Co., 1963, p. 638, 639.

Description of a method of laser light down-conversion and amplification in microwaves by a parametric amplifier with a glass sealed parametric diode. Two frequency-components of ruby laser-light are mixed in a parametric diode, and their beat frequency component, about 4,000 Mc in the present case, is amplified by the same low noise parametric amplifier. The detailed experimental results are presented. A semiconductor point contact was tested to check the possibility of detection of the microwave signal in laser light, with the following result: the diode, Nippon Electric GSB-1, silver-bonded germanium, glass-sealed, parametric type, was placed in a parametric amplifier and illuminated by ruby laser light through a hole in the cavity wall. The ruby laser, Raytheon model LH-1, was pumped at the level of 288 joules. The ruby crystal was 0.05% chromium-ion doped. The laser light was reflected by a half-mirror and supplied through the hole to the diode without collimation or focusing. Behind the mirror, a phototube was placed as a light monitor. When no parametric pumping power was applied, only short and sparse impulses were observed. When the pumping power was supplied, the gain as an ordinary amplifier was approximately 15 db.

A64-15218**SORTING OF AMMONIA MOLECULES IN A MASER.**

O. I. Mednikov and V. H. Parygin (Moscow State University, Physics Institute, Moscow, USSR).
(*Radiotekhnika i Elektronika*, vol. 8, Apr. 1963, p. 653-658.)
Radio Engineering and Electronic Physics, vol. 8, Apr. 1963, p. 685-690. 12 refs. Translation.

Comparison of the effectiveness of the sorting of molecules of ammonia in a maser with transverse and longitudinal electrostatic fields. Sorting systems in the form of a bifilar helix and an assembly of diaphragms are investigated theoretically and experimentally. The greatest maser power was obtained with a bifilar helix system. The dependence of the power generated on the length of the sorting system is studied for a system of diaphragms.

A64-15240**THE PREDICTION OF THE OPTIMUM NOISE PERFORMANCE OF A REFLECTION CAVITY MASER.**

C. R. Ditchfield (Ministry of Aviation, Royal Radar Establishment, Great Malvern, Worcs., England).
(*Symposium on Masers and Lasers*, London, England, Jan. 2, 1963.)
Radio and Electronic Engineer, vol. 27, Feb. 1964, p. 149-152; Discussion, p. 152.

Maser performance depends on the microwave circuit, on the total concentration of paramagnetic centers in the energy states used in the crystal and on the degree of inversion of population differences which can be obtained by pumping. At any temperature there will be an optimum concentration for maximum performance and to determine this optimum a knowledge is needed of certain parameters. Although some of these are difficult to measure directly, a method is suggested which enables an adequate determination to be made.

A64-15245**NOISE PERFORMANCE OF TRAVELING-WAVE MASERS.**

W. H. Higa (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.).
IEEE Transactions on Microwave Theory and Techniques, vol. MTT-12, no. 1, Jan. 1964, p. 139.
Contract No. NAS 7-100.

Review of the noise performance of traveling-wave masers (TWM). It is shown in particular that when the gain per unit length of structure is low, the equivalent noise temperature of the TWM can become appreciable.

A64-15270**PULSED HELIUM-NEON GAS LASER APPLICATIONS.**

L. L. Antes, J. Goldsmith, and W. McMahan (Martin Marietta Corp., Martin Co., Orlando, Fla.).
IEEE Transactions on Military Electronics, vol. MIL-8, Jan. 1964, p. 3-12. 27 refs.

The pulsed helium-neon gas laser has provided pulse power more than three orders of magnitude above the average power afforded by CW operation. Analyses of the power-limiting factors show that still greater increases may be expected. By increasing the size of the laser tube several times, by optimizing the gas ratio and pressure, by optimizing reflectivity and transmissivity of the reflecting mirrors, and by controlling the shape and application of the exciting voltage pulse, peak power outputs in the kilowatt range are theoretically possible. A power of 100 watts has been achieved in the laboratory at pulse rates up to 250 cps. Such a result brings the gas laser out of the low power category and into the intermediate power range. The results of range calculations show that 100 w pulse power will provide a radar range of approximately 10 km against a target having a diffuse reflectivity of 0.1, and a range of over 100 km with a cooperative target. Against a bright cloud background only the cooperative target can be used. The range will then be reduced to approximately 20 km. An automatic tracking radar system has been synthesized utilizing the pulsed gas laser as a transmitting component. A brief parametric analysis has been made and some of the advantages of the optical radar over its microwave counterpart have been outlined.

A64-15271**ANALYSIS AND OPTIMIZATION OF LASER RANGING TECHNIQUES.**

Graham W. Flint (Martin Marietta Corp., Martin Co., Orlando, Fla.).
IEEE Transactions on Military Electronics, vol. MIL-8, Jan. 1964, p. 22-28.

Presentation of the general criteria for the operational performance of laser ranging systems considered in quantitative terms with emphasis being placed on the optimization of systems which must meet specific operational requirements. The entire range-determining process is discussed on a statistical basis and the target detection capabilities of a system are defined in terms of the relative probabilities of recording real and false targets. Within this analysis appears a detailed discussion of all contributing noise sources, these being reduced to a fundamental noise source for two specific systems which transmit at different frequencies. A comparison is then made between the relative power requirements of the two systems performing the same task. In the case of some pulsed gas lasers, the pulse duration is somewhat long, thus necessitating a compromise between range resolution and maximum range capability. The relationship between these parameters is discussed in detail. In addition, a technique is proposed whereby the resolution is varied as a function of target return. This technique employs a multiple pulse transmitter and automatically optimizes its resolution and range capabilities.

A64-15500**OPTICAL AND INFRA-RED MASERS.**

Arthur L. Schawlow (Stanford University, Dept. of Physics, Stanford, Calif.).

Contemporary Physics, vol. 5, Dec. 1963, p. 81-102. 69 refs.

Discussion of masers (lasers) which operate at infrared, visible, or shorter wavelengths. The extent of development of masers (lasers), their closeness to scientific and technical applications, and their future prospects are discussed. Discussed also are the fundamental principles of operation of masers or lasers, laser materials, methods of excitation, gas-discharge-optical masers, semiconductor masers, giant-pulse lasers, and extremely monochromatic optical masers. It is shown that optical masers can produce light which is powerful, monochromatic, directional, and coherent. They now exist at wavelengths from 0.594 micron in the visible spectrum, to 35 microns in the infrared spectrum. Some strong indication of stimulated emission, but probably not true maser action, has been obtained at wavelengths as short as 3100 Å in the ultraviolet. Possibly the most important scientific results obtained so far have been in opening the field of nonlinear optics.

A64-15503**LASERS AND COHERENT LIGHT.**

A. L. Schawlow.

Physics Today, vol. 17, Jan. 1964, p. 28-33. 7 refs.

General description of lasers and their capabilities. Compared with ordinary light, laser light is powerful, monochromatic, directional, and coherent. Materials available to provide amplification by stimulated emission are examined, with ways by which the necessary excited atoms, molecules, or electrons are produced. Ruby-based lasers can give a very intense burst of well-collimated monochromatic light. High peak light-power outputs can be obtained by giant pulses followed by travelling wave amplification. At lower field strengths, refractive indices of many materials become noticeably nonlinear, leading to generation of harmonics having two or three times the frequency of the input light. Gas discharge masers and their characteristics are discussed.

A64-15548**LASERS AND THEIR APPLICATIONS.**

D. A. Buddenhagen (Hughes Aircraft Co., Components Group, Electronic Products Div., Newport Beach, Calif.), Society of Automotive Engineers, Automotive Engineering Congress, Detroit, Mich., Jan. 13-17, 1964, Paper 819A. 13 p. 18 refs. Members, \$0.75; nonmembers, \$1.00.

Discussion of various types of lasers and several applications for lasers which are most promising. The fundamental principles of laser action are explained in terms of fluorescent processes in certain materials, and the concepts of optical amplification and oscillation are developed. The properties of lasers are presented, and over 50 active laser materials are tabulated. Applications in many fields, such as micromachining, microwelding, photography, communications, optical ranging, metrology, chemistry, biological sciences, and others, are discussed.

A64-15564**INTERFERENCE EFFECTS IN LASER SYSTEMS [OB INTERFERENTSIONNYKH IAVLENIYAKH V LAZERNYKH SISTEMAKH].**

V. L. Strizhevskii, Optika i Spektroskopiya, vol. 16, Jan. 1964, p. 169-171. 18 refs. In Russian.

Discussion of some peculiar features of interference effects in lasers, produced by multiple reflections of the light beam. The analysis is based on the assumption of a constant excess population of the upper states (ΔN). It is set forth in analogy with the theory of linear light-wave amplifier but, in addition, takes into account the presence of not one but many beams of various frequency and various directions of propagation. The calculations show that at nearly constant ΔN , near the generation threshold, the intensity distribution over the interference fringes remains roughly constant, and only a broadening of the fringes is to be observed.

A64-15626**LASER BEAM FUSION WELDING.**

R. H. Fairbanks, Sr., (Technical Research Group, Inc., Syosset, N. Y.) and C. M. Adams, Jr. (Massachusetts Institute of Technology, Cambridge, Mass.), (American Welding Society, National Fall Meeting, Boston, Mass., Sept. 30-Oct. 3, 1963.)

Welding Journal, Research Supplement, vol. 43, Mar. 1964, p. 97-s-102-s.

Development of generalized relationships for pulsed heating of sheet material using high intensity sources which deliver heat to a circular area on one surface of the sheet. Engineering equations are presented which can be used to predict workable programs for such processes as laser beam welding. Experimentally, these relationships are validated for the Fe-group metals and their alloys, some Al and Cu-base alloys, and Ti. The experimental studies, viewed from a mathematical standpoint, indicate a safe maximum top-to-bottom temperature ratio (factor) during fusion of about three. It appears that a factor of about 4 or 5 would be safe for Cu and the precious metals, which appear capable of withstanding very high temperatures. This capability, together with their characteristic high thermal diffusivity, makes metals like Cu, Ag, and Au ideally suited to laser welding.

A64-15710**THE PERIODIC RELAXATION OSCILLATIONS AND SPIKELESS EMISSION OF A SHORT RUBY LASER [PERIODISCHE RELAXATIONSSCHWINGUNGEN UND EMISSION OHNE SPIKES BEI EINEM KURZEN RUBINLASER].**

Karl Girs (Siemens und Halske AG, Forschungslaboratorium, Munich, Germany).

Zeitschrift für Naturforschung, vol. 18a, Dec. 1963, p. 1363-1365. 6 refs. In German.

Experimental investigation showing that for a ruby laser with spherical mirrors at each end of the crystal, a resonator efficiency equal to that of lasers with large mirror spacing can be achieved, resulting in periodic damped relaxation oscillations in accordance with the theoretically predicted emission process. For high pumping efficiency, the emission becomes continuous after a certain build-up period. Low pumping efficiencies result in periodic emission pulses.

A64-15765**LASERS.**

A. L. Mikaelian and Iu. G. Turkov.

(Radiotekhnika i Elektronika, vol. 8, May 1963, p. 731-758.)

Radio Engineering and Electronic Physics, vol. 8, May 1963, p. 757-778. 77 refs. Translation.

[For abstract see Accession no. A63-23016 21-25]

A64-15825**LASER ACTION IN A FLUX-GROWN RUBY.**

D. F. Nelson and J. P. Remeika (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Journal of Applied Physics, vol. 35, pt. 1, Mar. 1964, p. 522-529. 30 refs.

A method of growing very perfect ruby crystals by slow cooling of a $\text{PbO}(\text{B}_2\text{O}_3)_x$ flux doped with Al_2O_3 and Cr_2O_3 is described. A crystal grown by this method has been operated as a laser with its natural crystal faces used as feedback surfaces. Interferometry through these surfaces showed that the optical path length between the feedback faces varied only about $\lambda/10$ for red light over the entire face. The angles of laser emission high above threshold agreed accurately with those predicted for a Fabry-Perot cavity. Near threshold the output consisted of a very regular damped oscillation of the Stutz-deMars type that was completely linearly polarized. A little farther above threshold a second train of oscillations was also present and was polarized at 90° to the first train. A formula for the laser threshold dependence on temperature was derived. A comparison of the model with measurements made between 90° and 305°K allowed a determination of the cavity loss under laser operation. With multilayer dielectric film reflectors a loss of less than 1% per pass was found, the bulk of which could be accounted for by known transmission and absorption losses in the end films.

A64-15833**ĆZOCHRALSKI GROWTH OF DOPED SINGLE-CRYSTAL LANTHANUM TRIFLUORIDE (LaF_3) FOR LASERS.**

M. A. Hiller (North American Aviation, Inc., North American Aviation Science Center, Canoga Park, Calif.) and O. M. Stafuss (North American Aviation, Inc., Atomic International Div., Canoga Park, Calif.).

Journal of Applied Physics, vol. 35, pt. 1, Mar. 1964, p. 693-695. 8 refs.

Development of a method of growing large, optically clear lanthanum trifluoride crystals. The method is quite simple and fast in that setup time per run is considerably shorter than that required by other growth methods.

A64-15878**A LASER EXCITED BY NUCLEAR HEAT.**

Fred M. Johnson (Electro-Optical Systems, Inc., Pasadena, Calif.), Nucleonics, vol. 22, Apr. 1964, p. 57-60. 13 refs.

Description of a method for the direct conversion of heat from nuclear fuel to coherent monochromatic optical radiation using a laser excited by an arc-mode-type gas discharge across a thermionic diode. In the method proposed, heat from a nuclear fuel is transferred to a cathode which causes electrons to be thermally emitted in a gas diode operated in the low-voltage, or arc-mode regime. The gas cell is so constructed as to constitute the laser itself. A detailed diagram of the laser device is presented. One of the unique features of the low-voltage arc is that, by proper choice of high work-function cathode and low-work function anode, an actual net electrical output is obtained as a by-product.

A64-15890

GENERATION OF ACOUSTIC SIGNALS IN LIQUIDS BY RUBY LASER-INDUCED THERMAL STRESS TRANSIENTS (EFFECT OF ACOUSTIC BOUNDARY CONDITION ON IMPULSE SHAPE - E/T). E. F. Carome, N. A. Clark, and C. E. Moeller (John Carroll University, Dept. of Physics, Cleveland, Ohio). Applied Physics Letters, vol. 4, Mar. 15, 1964, p. 95-97. Navy-supported research.

Study of a laser beam, consisting of a single 0.1-J impulse ~ 50 nsec wide, expanded to illuminate a 1.3-cm-diam. area on the sample. The measurements were made with and without a glass-backing-plate in contact with the illuminated interface to study the effect of altering the acoustic boundary conditions. A 0.64-cm-diam., 2.5-cm-long piezoelectric transducer was mounted flush with the bottom of the sample holder, coaxial with the laser beam. An RC differentiator was used to obtain the time variation of the stress itself. It is noted that the analysis of the results obtained seems to indicate that the acoustic signals are produced by transient heating. When the optical impulse is absorbed in the liquid, the temperature T of the absorbing layer increases within the duration τ of the impulse, and the temperature rise should fall off exponentially with increasing depth. The gradients of the resulting thermal stress then act as sources of acoustic waves, which should be generated adiabatically in samples of low thermal conductivity. There is good agreement between the time variation and relative amplitudes of the experimental and theoretical stress profiles. The results appear to confirm that transient heating is the source of the acoustic transients observed.

A64-15898

FLUCTUATIONS IN A LASER BEAM OVER 9- AND 90-MILE PATHS.

W. R. Hinchman and A. L. Buck (National Bureau of Standards, Radio Systems Div., HF/VHF Research Section, Boulder, Colo.). IEEE, Proceedings, vol. 52, Mar. 1964, p. 305, 306.

Presentation of some preliminary results of a study of long-distance laser transmission. The study has been carried out to determine the properties of a coherent optical beam which has been transmitted horizontally through the atmosphere over two test paths, one 9 miles long, and the other 90 miles long. Diagrams showing amplitude fluctuations and the spectrum of intensity variations in

A64-15899

NOISE-MODULATED OPTICAL RADAR.

Hans E. Band (Concord Radiancance Laboratory, Bedford, Mass.). IEEE, Proceedings, vol. 52, Mar. 1964, p. 306, 307. 14 refs.

Brief discussion of several methods of modulating radar carrier signals with random or quasi-random noise proposed by several investigators for nonambiguous measurement of distance and velocity. A new device, a noise-modulated continuous-wave (CW) optical radar for nonambiguous distance measurement, is suggested. In this device, artificially produced random noise with a suitably shaped power spectrum is impressed as amplitude, frequency, or phase modulation on a suitable steady-state optical carrier of coherent or noncoherent nature. The radar echo signal is cross-correlated with a delayed portion of the transmitted signal by allowing both to impinge simultaneously on a photoelectric device. The delay is varied until the cross-correlation function becomes maximum, at which time the delay gives the distance traveled by the emitted signal, and hence the radar range.

A64-16299

OFF-AXIS PATHS IN SPHERICAL MIRROR INTERFEROMETERS. D. Herriott, H. Kogelnik, and R. Kompfner (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

Applied Optics, vol. 3, Apr. 1964, p. 523-526. 6 refs.

Investigation of the properties of interferometers formed of spherical mirrors at other than confocal spacings, stemming from the use of nonconfocal systems as resonators for optical maser oscillators. It is noted that, when a spherical mirror interferometer is illuminated by an off-axis ray of light, the repeated reflections cause the ray to trace a path which lies on the surface of an hyperboloid, with the points of reflection on the mirrors on ellipses. Under special conditions, these ellipses may become circles, with the points of reflection displaced by an angle 2θ after

every round trip. When $2v\theta = 2\mu\pi$, v and μ being integers, the rays retrace their paths. These ray paths give rise to additional resonances which were observed. Pictures of the points of reflection are reproduced. The theory is stated to be in good agreement with the experimental observations. In laser amplifiers, these ray paths make possible the obtaining of long effective path lengths in the active medium which may be contained in a thin annular cylindrical or hyperboloidal shell.

A64-16300

THERMAL EFFECTS IN LASER AMPLIFIERS AND OSCILLATORS. A. E. Blume and K. F. Tittel (General Electric Co., Advanced Technology Laboratories, Schenectady, N.Y.).

Applied Optics, vol. 3, Apr. 1964, p. 527-530. 12 refs.

Discussion of the causes and implications of thermally induced optical effects in solid-state laser materials. A convenient interferometric method is described for examining the transient optical phenomena produced by thermal expansion, such as the change of refractive index with temperature and strain, in a typical helical and linear laser configuration. The results obtained with a neodymium laser glass rod are presented photographically.

A64-16301

THE USE OF A SINGLE PLANE PARALLEL PLATE AS A LATERAL SHEARING INTERFEROMETER WITH A VISIBLE GAS LASER SOURCE.

M. V. R. K. Murty (Rochester, University, Institute of Optics, Rochester, N.Y.).

Applied Optics, vol. 3, Apr. 1964, p. 531-534. 6 refs.

NASA-supported research.

Description of a shearing interferometer which makes possible the attainment of a high-intensity interference pattern, by the use of a visible gas laser and a simple construction. The high intensity of the laser per unit of solid angle gives an interference pattern that is visible in room light. The narrow spectral width of the source allows a simple plane parallel plate to be used to obtain the desired shear. Shown is a scheme which overcomes the limitation constituted by the size of the plate available in the biggest aperture optical system that could be tested. As a simple situation, a large spherical mirror is shown as the optics under test. The diverging light from the microscope objective strikes the spherical mirror from the center of curvature (slightly off-center) and is re-imaged near the microscope objective. This light is diverted into the interferometer consisting of the parallel plate and two well-corrected lenses. Thus, the lateral shear in collimated light is converted to lateral shear in diverging light. The interference pattern can be projected on a screen as large as the mirror itself.

A64-16303

NONLINEAR PHOTOCELL RESPONSE DUE TO LASER BEAM SPREAD.

M. Stimler and G. P. Worrell (U.S. Naval Ordnance Research Laboratory, Silver Spring, Md.).

Applied Optics, vol. 3, Apr. 1964, p. 538, 539.

Demonstration that photocell nonlinearity is introduced in typical measurements of laser output energy. By a simple optical analogy, it has been shown that nonlinearity results from small changes in beam divergence. It is noted that, where changes in laser beam divergence are comparable, such effects should be taken into account for accurate measurements.

A64-16304

PHOTOBEATS BETWEEN MODES IN RUBY LASERS.

M. Silver, R. S. Witte (Space Technology Laboratories, Inc., Redondo Beach, Calif.), and C. M. York (California, University, Los Angeles, Calif.).

Applied Optics, vol. 3, Apr. 1964, p. 539-540. 8 refs.

Continuation, with more detailed data concerning the "photobeats," of the work of Clark and others, who first observed a 40-Mc intensity modulation of the coherent radiation from a ruby laser by using a high-speed streak camera. They had suggested a possible explanation of the modulation in terms of the oscillation of a resonant cavity. It is noted that the low-frequency photobeats, observed in the frequency range from 36 Mc to 254 Mc, can be attributed to the interference of transverse cavity modes, as originally suggested. Similar low-frequency interference photobeats have

been observed by Stickley, using a photomultiplier tube to detect the intensity variation of the emitted light. Although this technique had neither the spatial resolution, nor the bandwidth of frequency response possessed by the fast camera, he was able to conclude that the observed interference was of the same frequency as that calculated for a cylindrical cavity from the theories of Schawlow and Townes and Barone. It is stated that a similar calculation, using the dimensions of the rubies studied in this work, gives equally satisfactory agreement with the observed photobeat frequencies. The conclusion is inferable that the photobeats of 1.7 Gc and higher result from the interference of longitudinal modes of the ruby cavity, while the photobeats in the range from 36 Mc to 254 Mc result from the interference of transverse modes.

A64-16306

BEAT FREQUENCIES OF $\text{CaWO}_4:\text{Nd}^{3+}$ MASER EMISSION.
Hansjoerg Manger (Karlsruhe, Technische Hochschule, Institut für Hochfrequenztechnik und Hochfrequenzphysik, Karlsruhe, Germany).

Applied Optics, vol. 3, Apr. 1964, p. 541, 542.

Observations regarding beat frequencies between axial modes in a pulse-operated optical maser. In the experiments, a $\text{CaWO}_4:\text{Nd}^{3+}$ rod of $L = 5.121 \pm 0.001$ cm length and with a 90° c-axis orientation was used at room temperature. A strong beat signal was obtained at a center frequency of 1522.1 ± 0.5 Mc having a width of 4 Mc, probably entirely due to spike modulation. The beat can be detected with any pump energy down to threshold condition for maser oscillations. With higher pump energy, a second beat signal was found, centered at 1509.7 ± 0.5 Mc. The threshold energy for the appearance of this latter beat frequency is higher by a factor of 1.7. The attempted interpretation of the lower frequency signal as beats between the lowest and a higher order of transverse modes was ruled out. It is noted that the correct interpretation seems to be based on the existence of separate indices of refraction for the ordinary and extraordinary rays, n_o and n_e , respectively.

A64-16309

THE TIME-RESOLVED SPECTRUM OF A NEODYMIUM GLASS LASER.

W. H. Keene and J. A. Weiss (Worcester Polytechnic Institute, Dept. of Physics, Worcester, Mass.).

Applied Optics, vol. 3, Apr. 1964, p. 545-547.

Time-resolution of the spectrum of a neodymium-in-glass laser. Described is the apparatus used and shown is a schematic diagram of the auxiliary optics used for time-resolved spectroscopy, with the entrance slit of the Jarrell-Ash spectrograph. It is noted that the time-dependence of the total light emission, as seen by a photocell with an S-1 surface, gave a series of uniformly spaced spikes decaying into steady emission, known as the "damped oscillation" type of behavior. Also shown are time-resolved spectrograms.

A64-16317

LASER MODES.

B. F. Hochheimer and J. T. Massey (Johns Hopkins University, Applied Physics Laboratory, Silver Spring, Md.).

APL Technical Digest, vol. 3, Jan.-Feb. 1964, p. 2-8. 15 refs.

Experimental investigation to determine, in a general way, the characteristics of the emission modes of a helium-neon gas laser. General methods for converting light sources into lasers are briefly considered, and the changes produced in the output radiation by the conversion are described. In the experiments, the laser consisted of a 1-m-long discharge tube, filled with a gas mixture of 90% He and 10% Ne. To study the phase variation over the transverse mode patterns, two-hole diffraction patterns, with each hole in a different part of the laser mode pattern, were analyzed. A Jamin and a Fabry-Perot interferometer were used to investigate the phase variations.

A64-16342

APPLICATION OF THE METHOD OF PROBABILITIES TO THE CALCULATION OF LASER OPTICAL CHARACTERISTICS [PRIMENENIE VEROIATNOSTNOGO METODA DLIYA RASCHETA OPTICHESKIKH KHARAKTERISTIK KVANTOVYKH GENERATOROV SVETA].

B. I. Stepanov and V. P. Gribkovskii.

Uspekhi Fizicheskikh Nauk, vol. 82, Feb. 1964, p. 201-220. 28 refs. In Russian.

Calculation of laser optical characteristics by Einstein's method of probabilities, using the energy levels and the transition probabilities between these levels as the initial data. The problem is reduced to the determination of the populations in the individual levels as a function of irradiation intensity, and the subsequent calculation of the number of optical transitions. It is noted that in the case of lasers it is necessary to take into account the transitions between the levels created both by the effect of pumping radiation and by the effect of the generated radiation proper.

A64-16513

CAVITY TUNING AND PRESSURE DEPENDENCE OF FREQUENCY IN THE HYDROGEN MASER.

J. Vanier and R. F. C. Vessot (Varian Associates, Beverly, Mass.).

Applied Physics Letters, vol. 4, Apr. 1, 1964, p. 122, 123.

Contract No. NAS 8-2609.

Experimental verification of the existence of a cavity setting for which the frequency shift with hydrogen pressure is zero, in tuning of the hydrogen maser cavity. The experiment was made on two masers beating against each other and by varying the hydrogen pressure at various cavity frequency settings. Hydrogen beam flux was controlled by varying the temperature of the palladium purifier. The beam source pressure, measured with a Pirani gage, and the period of ten beats, were recorded simultaneously. The results are shown for four different source pressures. These data were analyzed by the method of least squares to give the equations of four intersecting straight lines; the spread at the crossing of the various pressure curves did not exceed 0.0003 cps or 2.1 parts in 10^{13} . It is concluded that, even considering the presence of pressure shifts, the hydrogen maser can be tuned with the technique described. Two masers were tuned by the method described. Their frequency difference, after tuning, was 7.6 parts in 10^{12} . The belief is expressed that the resettability of the tuner of one of the masers was the limitation in this experiment.

A64-16517

LIMITATIONS ON LASERS FOR DEEP SPACE COMMUNICATION.

L. R. Bittman (Martin Marietta Corp., Martin Co., Baltimore, Md.).

(Institute of Electrical and Electronics Engineers, Winter General Meeting, New York, N. Y., Jan. 27-Feb. 1, 1963, Paper 63-57.)
IEEE Transactions on Communication and Electronics, Mar. 1964, p. 170-173.

Comparison of immediately foreseeable laser communication systems with conventional radio systems, taking as optimum that system which transfers a given rate of information with minimum power energy supply. It is shown that the energy associated with extremely high frequency photons of laser communication systems decreases their efficiency. The increased efficiency made possible by narrower beamwidths at visible light frequencies more than compensates for this photon energy factor, but if reliability in reception is to be maintained, extremely narrow beamwidths are forbidden unless elaborate precision tracking gear is used and the receiver position is accurately known. It is considered that the 8- μ to 13- μ infrared range is optimum for space communications.

A64-16556

PULSE SHARPENING AND GAIN SATURATION IN TRAVELING-WAVE MASERS.

E. O. Schulz-DuBois (Karlsruhe, Technische Hochschule, Karlsruhe, Germany; Bell Telephone Laboratories, Inc., New York, N. Y.).
Bell System Technical Journal, vol. 43, Mar. 1964, p. 625-658. 24 refs.

Contracts No. DA-36-039-SC-73224; DA-36-039-SC-85357.

Derivation of a pair of coupled nonlinear differential equations describing the reduction of gain in a traveling-wave maser due to high-power signals. Integrals in closed form are obtained for two cases of interest. The first applies to pulsed optical amplifiers where no replacement of stored energy occurs during a signal pulse. The result is a pulse-sharpening phenomenon: the leading edge of an input pulse is amplified by the original full gain while later parts of the signal experience reduced gain. The second case is that of steady-state gain saturation in the presence of a continuous pumping process. The results describe the observed gain compression of microwave ruby traveling-wave masers.

A64-16564**INTERFEROMETRIC INVESTIGATION OF MODES IN OPTICAL GAS MASERS.**

Thomas G. Polanyi and William R. Watson (General Telephone and Electronics Laboratories, Inc., Bayside, N. Y.).
Optical Society of America, Journal, vol. 54, Apr. 1964, p. 449-454. 17 refs.

Experimental investigation to determine whether measurements with a Fabry-Perot interferometer are well suited for analyzing the number and the relative amplitude of simultaneously oscillating modes in 6328-Å He-Ne optical gas masers. In one case, 28 dominant modes spanning a frequency range of 1080 Mc out of the 1500 Mc half-width of the 6328-Å Ne line were found. The relative amplitudes of the modes can be fitted generally to a Gaussian-shaped curve. It is shown that the wide adjustable frequency range of the interferometer and the absence of ambiguity in the interpretation of results are important features of this method. The technique makes feasible the analysis of the output of IR optical masers in a range of frequencies where only slow detectors are available.

A64-16729**THE CENTER-FREQUENCY PROPERTIES OF NEGATIVE-CONDUCTANCE AMPLIFIERS.**

Alan C. Macpherson (U.S. Naval Research Laboratory, Washington, D. C.).
IEEE Transactions on Circuit Theory, vol. CT-11, Mar. 1964, p. 136-145. 14 refs.

Masers, tunnel diodes and parametric devices, in their simplest forms, can each be described at a center frequency as a linear noisy negative-conductance one-port. Various coupling schemes may be used to convert the one-port to a two-port amplifier. This two-port, in turn, is useful as a low-noise preamplifier feeding a high-gain postamplifier or receiver. The properties of the "over-all amplifier" can be calculated from the noise properties of the negative-conductance one-port, the coupling scheme and the properties of the receiver. Four of the most popular coupling schemes are considered in detail and the minimum achievable noise figure for each case, regardless of the receiver, is $1 + t$, where t is the noise temperature ratio of the negative-conductance one-port. In each case the conditions for minimum noise figure require also that the over-all amplifier be infinitesimally close to the oscillating condition. This suggests the introduction of a stability factor S which approaches zero as the over-all amplifier nears the oscillating condition. Then, when a condition of finite stability (finite positive S) is imposed, clearcut differences between the different coupling schemes appear and the noise properties of the receiver come into the picture. It is shown that coupling which is restricted to reciprocal networks is definitely inferior to circulator coupling. The stability factor S can be related to allowable tolerances in the negative conductance and in other circuit variables as, for example, the source conductance. Experimental and theoretical methods of determining t are discussed.

A64-16963**PHOTON AVALANCHES FROM A POPULATION INVERSION.**

Lewi Tonks (General Electric Co., Advanced Technology Laboratories, Schenectady, N. Y.).
Journal of Applied Physics, vol. 35, Apr. 1964, p. 1134-1141.

Development of an approximate high-power laser model to study the increasing losses of stored energy from stimulated emission by once-through avalanches of photons as the power increases. The model exhibits the expected linear increase of outgoing photon flux near the end of the rod and the huge depletion of excited atom population away from the rod equator. A criterion is developed for the maximum useful excitation relative to emission parameters; rod length, and rod cross section. It is shown that this excitation level is fairly insensitive to aspect ratio (radius/length) but that internal reflection from the rod cylindrical surface can markedly lower this level by increasing the effective aspect ratio enormously.

A64-16967**USE OF TIME RESOLUTION IN IDENTIFYING LASER TRANSITIONS IN A MERCURY-RARE GAS DISCHARGE.**

W. M. Doyle (Hughes Aircraft Co., Aerospace Group, Culver City, Calif.).

Journal of Applied Physics, vol. 35, Apr. 1964, p. 1348, 1349.

Discussion of observations of laser action at six wavelengths in the micron range in a pulsed discharge. The apparatus consists of a quartz discharge tube with internal electrodes and calcium fluoride windows and a near confocal resonator utilizing deposited silver reflectors thinly coated with magnesium fluoride. A lead selenide photoconductive detector and a Gaertner rocksalt monochromator measured the laser output. Driving energy was supplied by discharging a capacitor through the tube at several pulses per second with a pulse length of a fraction of a microsecond. Emission during the discharge and the time development of the output are monitored, and the possible electron transitions are determined for the various wavelengths.

A64-17170**DESIGN AND PRINCIPLES OF A He-Ne MOLECULAR GAS LASER [KONSTRUKCE A TECHNOLOGIE PLYNOVÉHO MOLEKULÁRNÍHO GENERÁTORU SVĚTLA He-Ne].**

F. Petrů, V. Boček, J. Kršek, and B. Popela.
Jemná Mechanika a Optika, vol. 9, Feb. 1964, p. 38-42. 12 refs. In Czech.

Description of the design and technology of a molecular gas laser with a discharge tube containing a He-Ne mixture. The device radiates at wavelengths of 1, 15, and 23 μm . In addition, the discharge tube and its filling, measurements of the glass smoothness and mirror transmission, and spectral measurements are described.

A64-17228**FIVE LAYER OPTICAL MASER AMPLIFICATION.**

H. Jacobs, F. A. Brand, L. Hatkin (U.S. Army, Electronics Research and Development Laboratories, Fort Monmouth, N. J.), and D. Holmes (Carnegie Institute of Technology, Dept. of Electrical Engineering, Pittsburgh, Pa.).
IEEE Transactions on Microwave Theory and Techniques, vol. MTT-12, Mar. 1964, p. 163-170. 6 refs.

Analysis indicating a method of designing an amplifier system consisting of multilayers. An optical maser is treated as a Fabry-Perot resonator with an active medium. Five layers are considered: air, reflector, active medium (ruby), reflector, and air. General equations are derived using the method of boundary value problems in which it is assumed that incident coherent radiation falls normally on the surface. It is suggested that the presence of lossless one-quarter wavelength reflectors will enhance the amplification of the device in that less pumping may be required for a given length of ruby. The role of the reflectors in oscillation conditions is shown to be of importance. Methods are indicated for the calculation of amplitude and phase for an idealized amplifier.

A64-17334**ACTIVE IMAGING.**

Wilton A. Hardy (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).
Nature, vol. 202, Apr. 18, 1964, p. 277, 278.

Application of the mode degeneracy of an optical cavity to image formation in the sense that opaque objects placed before the mirror control the resultant field distribution in maser oscillations. In turn, the light generated within the cavity and partially transmitted through one mirror is used to re-image the object. Specific attention is directed to the fact that such images may have a contrast or resolution an order of magnitude greater than would be obtained by conventional diffraction-limited image formation.

A64-17340**THEORY OF PHONON-TERMINATED OPTICAL MASERS.**

D. E. McCumber (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Physical Review, 2nd Series, vol. 134, Apr. 20, 1964, p. A299-A306. 34 refs.

Application of a simple dielectric theory to describe the operating properties of phonon-terminated masers of the type reported by Johnson, Dietz, and Guggenheim. Basic to the model is a broadband gain characteristic which describes the frequency-dependent gain of the active maser material as a function of the populations of metastable electronic levels and of the temperature

or temperatures describing lattice vibrations. The power levels required to produce phonon saturation are estimated to be extremely high. Because phonon saturation does not ordinarily occur, a single-lattice structure is generally sufficient. In that case, details of the electron-phonon coupling are unimportant, and the gain can be related by detailed balance to fluorescence and absorption spectra. Effects of phonon saturation are briefly discussed in the event that they might pertain to exceptional systems and because they give insight into the principles of operation of these masers.

A64-17349**MASERS AND LASERS.**

Gordon Troup (Monash University, Victoria, Australia).
New York, John Wiley and Sons, Inc.; London, Methuen and Co., Ltd., 1963. 192 p. 118 refs.
\$4.50.

This treatise comprises a survey of the state of the maser and laser art, following the historical order of development. It is directed to advanced students and workers in the field. The following subjects are treated: general principles; stimulated and spontaneous emission of radiation from the thermodynamic and quantum mechanics approaches; amplification; excitation methods; microwave amplifier systems; the microwave maser oscillator; infra-red and optical masers; experimental work; and applications and future work. Two appendices, discuss quantum mechanical treatment of the harmonic oscillator, and the theory of paramagnetic ions in a crystal field and a steady magnetic field. Supplementary material includes a bibliography of seventeen works, and an index.

A64-17358**STUDY OF PULSED LASER GENERATION IN NEON AND IN MIXTURES OF NEON AND HELIUM.**

G. G. Petrash and I. N. Kniazev (Academy of Sciences, Physics Institute, Moscow, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 45, Oct. 1963, p. 833-839.)

Soviet Physics - JETP, vol. 18, Mar. 1964, p. 571-575. 8 refs. Translation.

Study of the character of laser generation under pulsed excitation for a wide range of partial pressures. In pure neon, peak generation is observed in three lines at the start of the excitation pulse, and continuous generation is observed in two of these lines. It is shown that the generation peak occurring at the start of the excitation pulse is due to peculiarities in the population of the different levels in the discharge. The generation peak occurring after switching off the discharge is considered to be due to the resonance transfer of energy from the long-lived metastable states of helium to the neon atoms.

A64-17360**RUBY LASER WITH GENERATION DURATION OF ~10 MILLI-SECONDS.**

V. K. Koniukhov, L. A. Kulevskii, and A. M. Prokhorov (Academy of Sciences, Physics Institute, Moscow, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 45, Oct. 1963, p. 857-862.)

Soviet Physics - JETP, vol. 18, Mar. 1964, p. 588-591. 8 refs. Translation.

Investigation of the spectral composition of a ruby laser within a temperature range of approximately 80° - 100°K operating with a generated pulse duration of approximately 10 msec. The spectrum at low temperatures and with a generated pulse duration of 1 msec consists of two separated components. The complete spectrum was photographed during a single flash and the length of exposure coincided with the duration of the pulse. With increase in generation time the complete spectrum broadens toward the red, and at 10 msec it occupies a band with no definite structure. The abrupt expansion of the total spectrum toward one side is explained by the gradual change in the generated frequency toward the red due to heating of the ruby crystal.

A64-17361**ON THE THEORY OF THE PULSATIIONS IN THE OUTPUT OF THE RUBY LASER.**

V. V. Korobkin and A. V. Uspenskii (Academy of Sciences, Physics Institute, Moscow, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 45, Oct. 1963, p. 1003-1008.)

Soviet Physics - JETP, vol. 18, Mar. 1964, p. 693-697. 12 refs. Translation.

Presentation of an explanatory theory connected with nonlinear effects in the interaction of the field with the medium. The pulsations are treated on the basis of general equations applicable to solid state lasers. Formulas are derived for the amplitudes and frequencies of the spikes as functions of the parameters characterizing the laser. The mechanism of the spiking is the transfer of particles from the upper level to the lower one with the radiation of energy, and in the opposite direction with absorption of energy. The theory is applied to the ruby laser and compared with experiment.

A64-17368**THE SCATTERING OF LIGHT BY LIGHT.**

V. M. Arutiunian, F. R. Arutiunian, K. A. Ispirian, and V. A. Tumanian (State Atomic Energy Commission Institute, Erevan, Armenian SSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 45, Oct. 1963, p. 1270-1272.)

Soviet Physics - JETP, vol. 18, Mar. 1964, p. 873, 874. 7 refs. Translation.

Theoretical calculation that light scattering by light could be accomplished by making use of high-intensity photons from laser radiation and gamma-quanta beams from high-energy electron accelerators. The estimated frequency of the events exceeds possible noise.

A64-17369**LASER ACTION IN AN UNBOUNDED PLANE-PARALLEL SLAB.**

B. I. Stepanov, A. M. Goncharenko, A. P. Ivanov, A. M. Samson, B. A. Sotskii, and A. P. Khapaliuk.

(Conference on Luminescence, 11th, Minsk, Belorussian SSR, Sept. 10-15, 1962.)

(Akademiia Nauk SSSR, Izvestiia, Seriya Fizicheskaiia, vol. 27, Apr. 1963, p. 460.)

Academy of Sciences, USSR, Bulletin, Physical Series, vol. 27, Apr. 1964, p. 462-467. 19 refs. Translation.

Consideration of the properties of the laser resonator containing the active medium, with limitation to a slab with plane-parallel faces of infinite transverse extent. It is stated that such a model serves as an approximation to real, bounded, plane-parallel cavities. The model is used in order to simplify the mathematical analysis. The concept of a generation (laser oscillation) threshold is derived. It is stated that, for generation to occur, a certain minimum amount of energy must be fed into the resonator. This energy is used, first, to produce a negative absorption coefficient (the amount of energy required depends on the luminescence characteristics of the material and thermal losses in it), and, second, to make up for all the external losses. It is concluded that, in the stable state, laser action will occur at the frequency which corresponds to the peak of the absorption band. It is this feature of stable generation which is responsible for its high monochromaticity. It is noted that the deviations from strict monochromaticity observed experimentally are due only to factors not included in the derivation performed, such as perturbations of the stationary state, the presence of external noise, and a frequency dependence of the reflectivity of the slab coatings.

A64-17371**INFLUENCE OF THE CHARACTERISTICS OF THE ACTIVE MEDIUM ON THE PROPERTIES OF THE LASER OUTPUT.**

B. I. Stepanov, A. M. Samson, and V. P. Gribkovskii.

(Conference on Luminescence, 11th, Minsk, Belorussian SSR, Sept. 10-15, 1962.)

(Akademiia Nauk SSSR, Izvestiia, Seriya Fizicheskaiia, vol. 27, Apr. 1963, p. 473.)

Academy of Sciences, USSR, Bulletin, Physical Series, vol. 27, Apr. 1964, p. 474-477. Translation.

Determination of the optical properties of the medium inside a laser resonator by methods of the theory of probabilities. It is stated that this method does not permit the determination of the spectral composition of the output radiation, but is adequate for

obtaining integral quantities. Equations are provided which give the steady-state populations of the energy levels. Also derived are equations which can be used for the analysis of the properties of four-level lasers and are applicable to many commonly encountered cases.

A64-17373

EFFECT OF NOISE ON LASER ACTION IN A BOUNDED PLANE-PARALLEL SLAB.

B. I. Stepanov, A. M. Samson, and Iu. I. Chekalinskaia.

(Conference on Luminescence, 11th, Minsk, Belorussian SSR, Sept. 10-15, 1962.)

(Akademiia Nauk SSSR, Izvestiia, Seriya Fizicheskaiia, vol. 27, Apr. 1963, p. 488.)

Academy of Sciences, USSR, Bulletin, Physical Series, vol. 27, Apr. 1964, p. 487-490. Translation.

Consideration of the effects of noise on the spectral width and angular distribution of the laser output in real laser systems. Considered is the case in which the noise is due to radiation incident to the slab from outside. It is, however, stated that for external radiation densities much smaller than the laser radiation density, the results also apply when the perturbing radiation is due to processes occurring inside the slab. Formulas are provided which show that, in different cases, there will be different dependences of the noise angular distribution on the properties of the cylinder. It is only with cylinders of finite radius and low side-wall reflectivity that one can obtain radiation with a high degree of directionality. Considered is the specific case where the thickness of the slab considerably exceeds its cross section, and the sidewall (lateral wall) transmits all the radiation incident to it.

A64-17541

NOISE MEASUREMENT IN AN He-Ne LASER AMPLIFIER.

R. A. Paananen, H. Stutz, D. L. Bobroff, and A. Adams, Jr. (Raytheon Co., Research Div., Waltham, Mass.).

Applied Physics Letters, vol. 4, Apr. 15, 1964, p. 149-151. 7 refs.

Investigation of noise in a nonresonant laser amplifier. The theoretical noise corresponding to a single mode was calculated and used in the Planck radiation law to determine the equivalent input noise power per mode. The theoretical noise output was obtained by integrating the product of this distribution times the gain factor of the amplifier over the complete frequency range. The noise was also determined experimentally and found to be slightly higher than the theoretical value. This discrepancy is attributed to limitations of the interference filter and to the fact that there are other transitions present with radiation frequencies so close to the frequency measured that they cannot be discriminated. It is felt that the optimal noise figure predicted by the Heisenberg principle can be approached with lasers.

A64-17542

METAL ION EMISSION VELOCITY DEPENDENCE ON LASER GIANT PULSE HEIGHT.

N. R. Isenor (Waterloo, University, Dept. of Physics, Waterloo, Ontario, Canada).

Applied Physics Letters, vol. 4, Apr. 15, 1964, p. 152-153.

Research Supported by the National Research Council of Canada.

Experimental investigation of the peak velocity of ions produced when the output of a giant-pulse ruby laser is focused on a metal. An oscilloscope triggered by the laser pulse is used to display the ion current, and another oscilloscope is used to display the laser output simultaneously. The target consisted of strips of zinc, lead, or magnesium. Typical ion and laser pulses are graphically presented. When double laser pulses are produced, the second pulse is almost always smaller than the first. The velocity of the fastest ions is graphically displayed as a function of the laser pulse height.

A64-17570

LASER GENERATION WITH INSTANTANEOUS Q SWITCHING.

A. M. Prokhorov.

(Radiotekhnika i Elektronika, vol. 8, June 1963, p. 1073, 1074.)

Radio Engineering and Electronic Physics, vol. 8, June 1963, p. 1065-1067. Translation.

Discussion of the possibility of generating short high-power light pulses by the use of lasers with rapid Q switching. It is stated that pulses with power of $5 \cdot 10^7$ watts and duration of 10^{-8} sec are presently attainable. The systems operate as follows: a pumping tube transfers most of the particles from a low level to a metastable level and then, with maximum speed, self-excitation conditions are created either by means of mechanical shutters, or by means of a Kerr cell. The conditions under which maximum power is obtained are explained, and the pulse duration is ascertained. As an example, a laser is investigated in which a ruby rod of 5-cm length and 1-cm² cross section is used with a chromium particle density of $2 \cdot 10^{19}$ cm⁻³. With complete inversion, the negative absorption is $\alpha \approx 0.4$ cm⁻¹. Setting is made of $u = 0.3$, that is, $\alpha = 0.13$ cm⁻¹. Then the peak radiation power, including all losses, is derived as $P_{\max} \approx 10^{10}$ watts. It is noted that during time τ_2 , nearly all the energy stored in the crystal is fluoresced.

A64-17608

RUBY LASER Q-SWITCHING ELEMENTS USING PHTHALOCYANINE MOLECULES IN SOLUTION.

P. P. Sorokin, J. J. Luzzi, J. R. Lankard, and G. D. Pettit (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

IBM Journal of Research and Development, vol. 8, Apr. 1964, p. 182-184. 10 refs.

Army-supported research.

Brief discussion of the use of metal phthalocyanine solutions in repeatable Q-switching elements of ruby lasers. It is felt that metal phthalocyanines, including the free base, that are dissolved in ordinary liquid organic solvents show enough bleachable absorber action at 6943 Å to serve as repeatable Q-switching elements for ruby lasers. By suitable adjustment of the concentrations of the solution, a ruby laser employing this type of Q-switching element will produce giant pulses rather than the normal lasing response.

A64-17634

PRECISE WAVELENGTH MEASUREMENT OF INFRARED OPTICAL MASER LINES.

Paul G. McMullin (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Applied Optics, vol. 3, May 1964, p. 641, 642. 7 refs.

An attempt is made to resolve some of the ambiguities concerning the identity of a number of lines on which optical maser oscillations have been reported. Several maser lines are identified through wavelength measurements, using a precision spectrometer. It is found that of twenty-two Ne lines observed, two have not been reported previously and two resolve an earlier ambiguous assignment. Eight Kr lines are seen, clearing up one ambiguity, and two Xe lines are observed due to very low concentrations of Xe present as an impurity in other gases.

A64-17635

THE DETERMINATION OF OPTICAL BANDWIDTH FROM PHOTOELECTRIC MIXING EXPERIMENTS WITH RUBY LASERS.

Morley S. Lipsett (Perkin-Elmer Corp., Norwalk, Conn.) and L. Mandel (London, University, Imperial College of Science and Technology, Dept. of Physics, London, England).

Applied Optics, vol. 3, May 1964, p. 643. 12 refs.

Research supported by the Department of Scientific and Industrial Research.

Presentation of the results of a determination of optical bandwidth from photoelectric mixing experiments using light beams from two completely independent ruby lasers. The results are summarized and compared with those of McMurtry and Siegman in order to obtain information on the nature of mode coupling. Beats between transverse modes which do not have a common geometry are observed as a first approximation to an investigation with independent beams. Almost steady beat notes are recorded for periods of order 10μ sec, and the observed beat spectrum is found to correspond to a spectral linewidth of order 100 to 200 kc.

A64-17636

INDEX OF REFRACTION MEASURED BY DOUBLE-SLIT DIFFRACTION OF COHERENT LIGHT FROM A GAS LASER.

R. L. Aagard, D. Chen, and G. N. Otto (Minneapolis-Honeywell Regulator Co., Honeywell Research Center, Minneapolis, Minn.). Applied Optics, vol. 3, May 1964, p. 643, 644.

Demonstration of the usefulness of a gas laser as a light source for refractive index measurements, particularly for the case of the average index of a bulk material rather than the index at the surface. The present work indicates the accuracy that can be achieved when interference of light is employed to measure index of refraction. A photograph showing the diffraction pattern and the slits in the aluminum film is included.

A64-17637

LASER ENERGY MEASURING DEVICE.

John A. Ackerman (Aircraft Armaments, Inc., Cockeysville, Md.). Applied Optics, vol. 3, May 1964, p. 644, 645.

Description of a simple calorimetric device for measuring the energy output of pulsed lasers. The complete device is shown to be easy and inexpensive to construct and to offer several advantages over the conventional conical configuration. It includes a bridge circuit and reference stack which corrects for ambient temperature variations.

A64-17747

MOMENTUM TRANSFER AND CRATERING EFFECTS PRODUCED BY GIANT LASER PULSES.

Frank Neuman (National Research Council, Ottawa, Canada). Applied Physics Letters, vol. 4, May 1, 1964, p. 167-169.

Comparison of impacts of giant and normal laser pulses. The giant laser pulse contained approximately 0.3 joules of energy, with a half maximum width of 50 nsec. The targets were attached to a piezoelectric momentum transducer. Laser pulse energy measurements were obtained by three independent means, and results agreed within a factor of two. Giant pulses were focused on three different types of materials, and the measured target momenta were tabulated relative to copper. To obtain comparisons, giant and normal pulses were used alternately on the same materials of the first type, and results tabulated. Target momentum was found to be a function of energy density, and for most materials the target momentum due to incidence was higher for giant pulses. The normal pulses removed more material. To develop a theory on laser pulse impacts, it is considered that additional parameters must be known.

A64-17912

OPTICAL RADAR RESULTS AND METEORIC FRAGMENTATION.

G. Fiocco (Massachusetts Institute of Technology, Dept. of Geology and Geophysics, and Research Laboratory of Electronics, Cambridge, Mass.) and G. Colombo (Smithsonian Institution, Astrophysical Observatory, Cambridge, Mass.; Padova, Università, Padua, Italy). Journal of Geophysical Research, vol. 69, May 1, 1964, p. 1795-1803. 30 refs.

Army-USAF-Navy-supported research; Grants No. NSG-419; No. NSG-87-60.

Recent optical radar experiments utilizing a ruby laser as the source of radiation have indicated the existence of a scattering layer in the upper atmosphere at an altitude between 110 and 140 km. The echoes have been tentatively interpreted in accordance with a model of meteoric fragmentation and have been related to other experimental results. By progressive fragmentation in its flight through the atmosphere, a meteoroid should show an enhancement of cross section which is responsible for those echoes. The atmosphere would be working as a "filter," and the average size distribution of micrometeorites would vary with the height.

A64-18266

FAST InSb PEM DETECTORS FOR OPTICAL MASER STUDIES TO 7 μ .

R. N. Zitter (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Review of Scientific Instruments, vol. 35, May 1964, p. 594-596. Contract No. AF 19(628)-1646.

Description of an indium antimonide photoelectromagnetic (PEM) detector which, operating at room temperature, has shown

capabilities as a fast demodulator for optical maser studies at wavelengths up to 7 μ , well beyond the spectral range of phototubes and Ge or Si photodiodes. The detector is found to respond to modulation frequencies of at least 150 Mc, and the use of more highly doped material could result in speeds up to 1 Gc. The construction of the detector is shown to be simple, no bias current is required, and detector response should be linear even for large incident intensities. The main disadvantage is the relatively small amount of output power and the consequent necessity of low noise amplifiers. An important application is the study of the high gain transitions in xenon and neon lasers.

A64-18343

VERDET CONSTANT OF THE "ACTIVE MEDIUM" IN A LASER CAVITY.

Irwin Tobias (Rutgers University, School of Chemistry, New Brunswick, N. J.) and Robert A. Wallace (General Telephone and Electronics Laboratories, Inc., Bayside, N. Y.).

Physical Review, 2nd Series, vol. 134, May 4, 1964, p. A549-A552. 8 refs.

Experimental determination of the Verdet constant of the "active medium" in a gas laser. A quartz, helium-neon laser having internal mirrors defining a hemiconcentric cavity is oriented coaxially within an electromagnet. The laser operates at a wavelength of 0.633 μ . The laser radiation is passed through a Nicol prism to a photomultiplier detector, the output of which is read simultaneously by a digital frequency meter and an oscilloscope. The frequency of the intensity modulation observed when the output of a gas laser in a homogeneous axial magnetic field is viewed through a polarizer is simply related to the Verdet constant of the "active medium." The Verdet constant obtained for "active" neon is 5.9×10^{-10} radian/cm-oersted. Theoretical expressions for the Verdet constant of a dilute monatomic gas at a frequency close to the center of a Doppler-broadened line are derived for each of the three allowed transitions. The experimental results and the theory are used to estimate the threshold values of the absorption coefficient and the population inversion density for the "active" neon.

A64-18372

ON INTERFERENCE EFFECTS IN LASER SYSTEMS.

V. L. Strizhevskii.

Optika i Spektroskopiia, vol. 16, Jan. 1964, p. 169-171.)

Optics and Spectroscopy, vol. 16, Jan. 1964, p. 92-94. 16 refs. Translation.

[For abstract see Accession no. A64-15564 09-25]

A64-18397

INVESTIGATION OF RELAXATION OSCILLATIONS IN THE OUTPUT FROM A RUBY LASER.

D. D. Bhawalkar, W. A. Gambling, and R. C. Smith (Southampton, University, Electronics Dept., Southampton, England).

Institution of Electronic and Radio Engineers, Symposium on Masers and Lasers, London, England, Jan. 2, 1963.)

Radio and Electronic Engineer, vol. 27, Apr. 1964, p. 285-291. 23 refs.

Discussion of measurements made on the spike pulses produced by the relaxation oscillation in the output of a laser employing a 90° ruby crystal. Pulse shape, width, height, the time interval between successive pulses, and the polarization of the pulses are measured. The rate equations describing the laser oscillation are solved for operation of the laser close to threshold. The solution predicts a shape for individual pulses that is proportional to an inverse square hyperbolic cosine function of the time. This functional relation is verified by experiments. The solution of the rate equations enables the diameter and population inversion of the contributing "filament" to be determined. The measurements on the pulse interval give the number of "filaments" active in the crystal at a given time. By using a Nicol prism, all the pulses are found to be equally linearly polarized.

A64-18408

MULTIMODE OSCILLATIONS IN SOLID-STATE MASERS.

H. Statz and C. L. Tang (Raytheon Co., Research Div., Waltham, Mass.).

Journal of Applied Physics, vol. 35, May 1964, p. 1377-1383. 8 refs. Contract No. AF 19(628)-3226..

Extension of a previous analysis, by the authors, on the effects of slow spatial cross relaxation restricted to longitudinal modes, to include off-axis modes. On the basis of this extension, the number of oscillating off-axis modes as a function of the various laser parameters is calculated. Using the results of this calculation, the expected beam angle of a laser can be predicted. A more detailed analysis of spiking behavior than that given previously is presented, and it is shown that, depending upon the laser parameters and the pump power, both regular and irregular spiking trains can be obtained.

A64-18410**MULTIMODING IN LASERS.**

R. H. Pantell (Standard Telecommunication Laboratories, Ltd., Harlow, Essex, England).

Journal of Applied Physics, vol. 35, May 1964, p. 1404-1408. 17 refs.

Army-USAF-Navy-supported research.

Analysis of a two-level electric dipole transition wherein the equilibrium population distribution is inverted. The appropriate equations of motion are solved to determine the steady-state oscillation conditions at the one frequency (ω_2) with the highest gain. Then, with steady-state oscillations at ω_2 , the equations of motion are used to determine the requirement such that the field at another circuit frequency will grow with increasing time. The result of these calculations is expressed in terms of a threshold condition for start of oscillation at ω_1 or ω_3 in terms of the output power at the oscillating frequency ω_2 . The spatial variations of the population difference per unit volume (ΔN) between the levels involved in the laser transition and the temporal variation of ΔN are considered as two separate problems. Emphasized is multimoding for axial modes. It is assumed that spatial cross-relaxation times are long and that the laser medium is sufficiently relaxed so that laser action occurs uniformly throughout the crystal.

A64-18432**ROTATION DETECTION WITH A "RING-LASER."**

P. G. R. King (Services Electronics Research Laboratory, Baldock, Herts., England).

Contemporary Physics, vol. 5, Apr. 1964, p. 280-283. 5 refs.

Description of a ring-resonator gas discharge laser able to detect very small angular rotations. As these rotations are measured by the laser relative to an inertial frame of reference, it is considered that the device, with further development, might have applicability as a means of improving performance in certain types of inertial navigation systems. A demonstration device was able to detect differences in rotation rates of 1 in 10^{12} .

A64-18438**FREQUENCY CHANGING OF LASER RADIATION.**

E. L. Thomas and J. K. Wright (U. K. Ministry of Aviation, Signals Research and Development Establishment, Christchurch, Hants., England).

Journal of Scientific Instruments, vol. 41, May 1964, p. 277-279.

Description of a method of shifting laser output bodily to another region of the spectrum, at the same time preserving the laser characteristics of coherence and monochromaticity. By using the techniques of harmonic generation and the stimulated Raman effect, a large number of laser-like outputs may be generated at discrete frequencies in the spectral range 40,000-400 cm^{-1} . To achieve field strengths of 10^4 volts cm^{-1} or more, a Q-switched laser system was incorporated in all equipment. Up to three Raman lines have been observed with cells of benzene, nitrobenzene, carbon disulphide and carbon tetrachloride inside the cavity formed by the static reflector and the ruby-air interface remote from it. With the same materials in a focused beam many Stokes and anti-Stokes Raman lines have been observed. Up to 30% of the original laser power has been converted into Raman frequencies.

A64-18977**ANOMALOUS ABSORPTION IN RUBY.**

F. A. Brand, H. Jacobs, S. Weitz, C. Lo Cascio (U. S. Army Research and Development Laboratory, Fort Monmouth, N. J.), and G. Novick (Monmouth College, West Long Branch, N. J.).

IEEE, Proceedings, vol. 52, Apr. 1964, p. 417.

Experimental investigation of severe resonance absorption in ruby lasers, in which both oscillator and amplifier rubies were 90° oriented and optically aligned in the same polarization. Tests were run in which the oscillator and amplifier were maintained at room temperature or at that of liquid nitrogen. An unexpectedly large attenuation in transmission was noted when the amplifier was pumped at liquid nitrogen temperatures. It was also noted that under room-temperature operation, the amplifier provides power gains of 1.0 and 2.0. A possible explanation for these phenomena is advanced, which involves the assumption that the inverted electron population in the amplifier is depopulated upward to a group or band of higher energy levels by the incoming oscillator pulse.

A64-18983**CONSIDERATIONS REGARDING THE USE OF SEMICONDUCTOR HETEROJUNCTIONS FOR LASER OPERATION.**

S. Wang and C. C. Tseng (California, University, Dept. of Electrical Engineering, Berkeley, Calif.).

IEEE, Proceedings, vol. 52, Apr. 1964, p. 426, 427.

Grant No. AF-AFOSR 139-63.

Comment on Kroemer's injection scheme that considers heterojunctions for possible laser action. Kroemer's proposal envisions the use of an indirect-gap semiconductor sandwiched between two direct-gap semiconductors of opposite types and presupposes that injected electrons and holes would be trapped in the center region by potential barriers at the two heterojunctions and that laser action would eventually occur at sufficiently high carrier injection levels. It is stated that Kroemer's argument is rather vague and misleading, and this present note discusses theoretical considerations of using heterojunctions for laser operations and pictorially presents another scheme for laser action. A comment by Kroemer, in reply to the present authors, is also included.

A64-18984**DIRECT OBSERVATION OF AXIAL MODE BEATING IN Q-SWITCHED RUBY LASERS.**

L. Waszak (TRG, Inc., Melville, N. Y.).

IEEE, Proceedings, vol. 52, Apr. 1964, p. 428.

ARPA-supported research; Contract No. AF 49(638)-673.

Review of direct observations of axial mode beating in Q-switched lasers using a special phototube assembly. The detecting system consists of an ITT FW-114 in a wideband microwave structure and a Tektronix 519 traveling-wave oscilloscope. The observations show the first-order axial mode beating of a ruby laser as amplitude modulation of the Q-switched pulse. The laser used consisted of a 7-cm by 1-cm ruby pumped by four FX38A's in elliptical reflectors. The laser is Q-switched by means of a prism rotating at 24,000 rpm and is capable of providing 0.75-joule 20-nsec pulses.

A64-18985**PROPOSAL FOR OBTAINING LASER BEAT FREQUENCY RADIATION IN THE FAR INFRARED BY THE SMITH-PURCELL EFFECT.**

A. J. Fox and N. W. W. Smith (Mullard Research Laboratories, Redhill, Surrey, England).

IEEE, Proceedings, vol. 52, Apr. 1964, p. 429, 430.

Brief discussion of the Smith-Purcell effect and its possible employment as a method for obtaining coherent radiation in the far infrared. An electron beam produces visible radiation when it is projected parallel to the surface of a metallic diffraction grating. The wavelength of this radiation varies with the beam velocity and the angle at which it is observed. The method of image charges and other techniques are used to study this effect. The possibility of constructing a system that would contain a Smith-Purcell "coupler" which avoids the charging difficulties associated with the dielectric type of Cerenkov coupler is considered.

A64-18986**MEASUREMENT OF CONTINENTAL DRIFT AND EARTH MOVEMENT WITH LASERS.**

William Honig (Honig Laboratories, Inc., Brooklyn, N. Y.).

IEEE, Proceedings, vol. 52, Apr. 1964, p. 430, 6 refs.

Brief consideration of the possibility of measuring the continental drift with helium-neon CW gas lasers. Measurements

on the stability of such lasers have given values of short-time frequency stabilities of 1 to 2 kc over several min, which correspond to a temporal coherence length of 10,000 miles for the short-time stabilities. A simple experiment is considered for which a Doppler shift in frequency would exist. Such an experiment would, perhaps, be carried out at locations where large bodies of land lie on both sides of a fault caused by Earth convection currents.

A64-18989**RESONATOR INFLUENCE ON TEMPORAL CHARACTER OF LASER OUTPUT.**

M. Katzman and J. W. Strozyk (U. S. Army, Electronics Research and Development Laboratories, Fort Monmouth, N. J.).
IEEE, Proceedings, vol. 52, Apr. 1964, p. 433, 434.

Experimental investigation of the influence of variations in the length of a spherical mirror resonator on the temporal character of a laser output. The experiment consists of varying the spacing between two spherical mirrors that are located at opposite ends of the ruby medium. A fast-response photomultiplier with a narrow-band interference filter and neutral density filters is used to attenuate the laser signal, and a phototube having a blue-green interference filter is used to monitor the pump source. The two signals are displayed simultaneously on a dual-beam oscilloscope. A second experiment is performed with similar apparatus to monitor the oscillation and output energy as a function of the mirror spacing. The production of regular spiking which damps out to roughly constant amplitude output and the frequency of the spiking can be controlled by the mirror spacing.

A64-18993**ATTENUATION OF LASER LIGHT BY A DIFFRACTION GRATING.**

Reinhold Gerharz.
IEEE, Proceedings, vol. 52, Apr. 1964, p. 438.

Description of an attenuation method of measuring the output energy of laser radiation. The principal element of this method is a coarse diffraction grating which attenuates the incident laser beam and produces a large number of diffraction orders of known intensity. An expression is obtained for the intensity ratio of the undiffracted beam to any one of the diffracted beams. A sketch of the optical system is included.

A64-18997**A COMPUTER APPROACH TO LASER DESIGN.**

T. G. Furnhagen (USAF, Office of Aerospace Research, Cambridge Research Laboratories, Microwave Physics Laboratory, Hanscom Field, Bedford, Mass.) and J. Lubelfeld (USAF, Air Force Institute of Technology, School of Engineering, Dept. of Electrical Engineering, Wright-Patterson AFB, Dayton, Ohio).
IEEE Transactions on Electron Devices, vol. ED-11, May 1964, p. 219-228, 5 refs.

Development of a computer program which calculates the efficiency of a pulsed four-level laser from the values of the system parameters and certain physically measurable characteristics of the laser material and the pumping source. The efficiency of a four-level laser system is defined as a product of six sub-efficiencies, each associated with one of the loss mechanisms operative in the system. Equations are derived which relate the sub-efficiencies to physically measurable parameters. The set of these equations constitutes the model for system efficiency, and, based on the model, a program is written for the IBM 1620 digital computer. A sample problem involving the design of a neodymium-doped glass laser oscillator is solved to illustrate the use of the model, and it is stated that the results of this analysis are in general agreement with known theoretical and experimental properties of the pulsed four-level laser. In general, the efficiency increases with length, radius, doping density, and pumping efficiency, and decreases as end reflectivities and pumping-pulse time-constant increase, within the restrictions imposed on the model by assumptions and approximations. The method presented permits approximation of the optimum design before actual physical construction of the system.

A64-19042**UNIFORM RELAXATION OSCILLATIONS IN SHORT RUBY LASERS OF THE PLANAR FABRY-PEROT TYPE [REGELMASSIGE RELAXATIONSSCHWINGUNGEN IN KURZEN RUBIN-LASERN VOM EBENEN FABRY-PEROT-TYP].**

Dieter Röss (Siemens und Halske AG, Zentral-Laboratorium, Munich, Germany).

Zeitschrift für Naturforschung, vol. 19a, Mar. 1964, p. 387-391, 9 refs. In German.

Description of a technique for simplifying and enhancing the temporal oscillation behavior of short ruby lasers of the Fabry-Perot type, when the light source is rotationally symmetric about the axis of the laser. The technique gives good accuracy when the laser and the light source are arranged symmetrically about an axis of an exfocal rotational-ellipsoidal mirror. When there is very low pumping efficiency or high resonator output, there appear periodically damped relaxation oscillations with continuous emission. The reversal of the damping of the relaxation oscillations, which occurs when there is a high quantum density in the resonator, is ascribed to an effect not accounted for by present-day theories. It is shown that, to obtain regular relaxation oscillations, it is important to have an undisturbed coupling between the laser modes.

A64-19074**CALCULATION OF PULSED-LASER INTENSITY [RASCHEIT INTENSIVNOSTI IMPUL'SNOGO LAZERA].**

M. L. Ter-Mikaelian.

Akademiia Nauk Armianskoi SSR, Doklady, vol. 38, no. 2, 1964, p. 105-110, 6 refs. In Russian.

Calculation of the intensity of laser pulsed radiation. The nature of laser pulsations and the amplification of the initial intensity of quanta during their motion through the laser are examined. The number of quanta that approach the output end plane of the laser is calculated and used to determine the output intensity as a function of time and laser parameters.

A64-19196**OPTICAL RADAR STUDY OF THE UPPER ATMOSPHERE.**

Robert A. Young (Stanford Research Institute, Menlo Park, Calif.).

Faraday Society, General Discussion on Chemical Reactions in the Atmosphere, Edinburgh, Scotland, Apr. 2, 3, 1964, Paper 3376, 4 p.

Discussion of the possibility of constructing and testing an optical radar system based on the recent development of high-power (100 watts or more) pulsed molecular-nitrogen gas lasers. It is stated that metastable nitrogen in the $A^3\Sigma^+$ state (lifetime ≈ 2 sec) could now be detected in concentrations of less than $10^5/\text{cm}^3$ in a uniform 100-m region. Energy released in the atmosphere by impinging particles will produce significant concentrations of this metastable molecule, and it is probable that measurable densities exist in auroral features. It is noted that prospects are good for producing a pulsed molecular laser emitting the N_2^+ first negative bands, and the N_2 second positive bands, which would provide an independent means of obtaining the N_2^+ and $N_2(B)$ density, and their spatial distribution.

A64-19290**FILLING FACTOR AND ISOLATOR PERFORMANCE OF THE TRAVELING-WAVE MASER.**

F. S. Chen and W. J. Tabor (Bell Telephone Laboratories, Inc., New York, N. Y.).

Bell System Technical Journal, vol. 43, May 1964, p. 1005-1033, 7 refs.

Contract No. DA-36-039-SC-89169.

Analysis of the filling factor and isolator performance of the traveling-wave maser (TWM), and comparison with measurements, in order to reduce the amount of experimental work involved in developing traveling-wave masers. It is stated that, although the discussion is centered on the comb-structure ruby TWM, the data provided also apply to other slow-wave structures using different active crystals. It is stated that, for the TWM using the 90°

operation of ruby and the comb as the slow-wave structure, the c axis of the ruby should be parallel to the z axis of the structure (the direction of the signal wave propagation) for the largest filling factor. The improvement of the filling factor by the proper orientation of the c axis of the ruby is stated to be larger at the lower signal frequencies because the transition probability is more nearly linear at those frequencies. It is noted that the isolator should provide sufficient reverse absorption to make the TWM short-circuit stable and yet add the minimum forward absorption to the TWM. Both the reverse and the forward absorption of the isolator depend critically on the size of the ferrite disks and the position in which they are imbedded in the comb structure.

A64-19291**THE COMB-TYPE SLOW-WAVE STRUCTURE FOR TWM APPLICATIONS.**

F. S. Chen (Bell Telephone Laboratories, Inc., New York, N. Y.). *Bell System Technical Journal*, vol. 43, May 1964, p. 1035-1066. 10 refs.

Contract No. DA-36-039-SC-89169.

Presentation of the space harmonic analysis of the dielectrically loaded comb structure as used in traveling-wave masers (TWM). The frequency-phase characteristics are computed by regarding each finger of the comb structure as a capacitive loaded transmission line. The impedance of the line is based on the space harmonic analysis. Computed data are found to be in agreement with experimental results and, in particular, it is confirmed that the frequency-phase relation depends critically on certain dimensions of the dielectric loading. The results of the analysis are used to derive criteria for the design of dielectrically loaded TWM comb structures, especially of structures with low group velocity which are suitable to provide simultaneously large gain and large instantaneous bandwidth.

A64-19349

SOME RESULTS OF AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF A MAGNETIC FIELD ON THE EMISSION SPECTRUM OF A RUBY LASER [NEKOTORYE REZULTATY EKSPERIMENTAL'NOGO ISSLEDOVANIYA VLIYANIYA MAGNITNOGO POLYA NA SPEKTR IZLUCHENIYA LAZERA NA RUBINE].

A. M. Kubarev and V. I. Piskarev (Gor'kovskii Gosudarstvennyi Universitet, Radiofizicheskii Institut, Gorky, USSR). *Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki*, vol. 46, Feb. 1964, p. 508-510. 7 refs. In Russian.

Presentation of the results of an experimental investigation on the splitting of lines generated by a ruby at a temperature of 120°K under the action of a pulsed magnetic field. It is noted that the retuning of frequency does not occur gradually but in jumps from one axial resonator mode to another. A regular decrease in the frequency of generation with time is observed at room temperature.

A64-19353

THE THEORY OF INDUCED COMBINATION RADIATION [K TEORII INDUTSIROVANNOGO KOMBINATSIONNOGO IZLUCHENIYA].

V. M. Fain and E. G. Iashchin (Gor'kovskii Gosudarstvennyi Universitet, Radiofizicheskii Institut, Gorky, USSR).

Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 46, Feb. 1964, p. 695-709. 17 refs. In Russian.

Discussion of the theory of two-quantum processes, with particular attention to the induced Raman effect. Fluctuation-dissipation theorems are derived which relate the induced two-quantum radiations to fluctuations in the presence of an external sinusoidal signal. Spectral intensities of the spontaneous and induced combination radiations can be linked by means of these theorems. The theory is applied in an investigation of electromagnetic waves in which induced Raman radiation is taken into account. It is also used for deducing the conditions of self-excitation of a Raman laser. The relationship between Raman and parametric systems is considered.

A64-19386

COHERENT INTERACTION LENGTH OF LIGHT WAVES IN A NON-LINEAR MEDIUM.

S. A. Akhmanov, A. I. Kovrigin, R. V. Khokhlov, and O. N. Chumnaev (Moscow State University, Moscow, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 45, Nov. 1963, p. 1336-1343.)

Soviet Physics - JETP, vol. 18, Apr. 1964, p. 919-924. 14 refs. Translation.

Experimental investigation of the factors determining the coherent interaction length of light waves when optical harmonics are generated by passing light from a ruby laser through crystals having nonlinear polarizability. It is shown that mean coherent lengths $l_c \approx 0.5$ cm can be obtained. It is also shown that the restrictions on the divergence of laser beams are very rigorous for large values of l_c . This results in very different maximum efficiencies of power and energy conversion in experiments on optical harmonic generation. An extra amplitude modulation of the harmonic radiation is noted, which is stated to result probably from fluctuations in the angular distribution of energy during a ruby laser pulse. The angular distributions of the harmonic and fundamental light beams are compared. The possibility of increasing l_c by employing an optical resonator is discussed briefly.

A64-19403

OSCILLATION EQUATIONS FOR LASERS WITH EXTERIOR MIRRORS AND FOR LASERS WITH NONUNIFORM INVERSION [SCHWINGUNGSGLEICHUNGEN FÜR LASER MIT ÄUSSEREN SPIEGELN UND FÜR LASER MIT UNGLEICHMÄSSIGER INVERSION].

Dieter Röss (Siemens und Halske AG, Zentral-Laboratorium, Munich, Germany).

Zeitschrift für Naturforschung, vol. 19a, Apr. 1964, p. 421-423. 11 refs. In German.

Analysis of the dependence of oscillations in a laser with exterior mirrors on the distance of the mirror from the active laser material. A one-mode laser is assumed, for which the interrelation between inversion and quantum number is described by coupled differential equations. For the calculations, the oscillation transit time is divided into a passive transmission of energy between the active material and the mirror, and an active amplification in the material itself. The linear approximation of the modified oscillations shows that the relaxation period is proportional to the square root of the relationship for the transit time, and that the damping period is dependent on the threshold pump rate and the quantum density.

A64-19405

POLARIZATION AND RELAXATION TIME AS A MEANS OF FREQUENCY DISCRIMINATION FOR LASER EMISSION WITH NEODYMIUM IN CALCIUM TUNGSTATE [POLARISATION UND RELAXATIONSZEIT ALS MITTEL ZUR FREQUENZWAHL FÜR DIE EMISSION DES LASERS MIT NEODYM IN CALCIUMWOLFRAMAT].

Karl Gürs (Siemens und Halske AG, Forschungslaboratorium, Munich, Germany).

Zeitschrift für Naturforschung, vol. 19a, Apr. 1964, p. 515, 516. 7 refs. In German.

Theoretical determination of the threshold value of a neodymium-doped calcium tungstate laser, when the laser oscillates simultaneously in two lines, 10,585 Å and 10,652 Å. Such oscillations are achieved by employing a glass plate instead of a polarization prism. The results show that simultaneous emission in both lines can be maintained at high pumping efficiencies without interference from the laser singing path. With a ruby laser, oscillations are possible in one line only.

A64-19449

EFFECT OF IMPURITY DISTRIBUTION ON SIMULTANEOUS LASER ACTION IN GaAs AT 0.84 AND 0.88 μ.

H. Nelson and G. C. Dousmanis (Radio Corporation of America, RCA Laboratories, Princeton, N. J.).

Applied Physics Letters, vol. 4, June 1, 1964, p. 192-194.

Description of a GaAs laser diode which can oscillate simultaneously at two wavelengths, about 8430 and 8800 Å. A figure shows the spectra obtained at 77°K from a diode with the diffused portion

of the P region 2- μ wide. The two incoherent emission peaks shift to shorter wavelengths with increasing current; A is the usual GaAs peak; B is the additional peak characteristic of the diode presented. It is stated that the shifts of the incoherent emission B with current, and its linewidths are similar to those of line A in the heavily doped, epitaxially grown units described earlier. The Zn and Sn concentrations in the epitaxial portion of the P layer are large and can create "tail" states with sufficient densities for stimulated emission from deep-lying states. It is noted that the insensitivity of the threshold to temperature suggests deep, but not necessarily discrete, states; the temperature dependence of the laser threshold for the usual GaAs laser line A depends strongly on doping. Low-doped units show a threshold rise of 10 to 30 times from 4.2 to 78°K.

A64-19483

DESIGN CONCEPTS FOR A LASER-PHOTON PROPULSION SYSTEM.

Lanny M. Englund (Michigan, University, Ann Arbor, Mich.).
AIAA Student Journal, vol. 2, May 1964, p. 3-5. 13 refs.

Presentation of a conceptual theoretical investigation into the possible future development of a pure or partial photon propulsion system utilizing the laser principle of stimulated emission of radiation as a means of photon production and collimation into a photon beam, to provide a propulsive thrust. The investigation is limited to a discussion of the present theoretical study of the ideal photon rocket, to a summary of basic laser technique, and to the conceptual application of the laser principle of stimulated emission of radiation to the theoretical photon rocket.

A64-19554

LASER OSCILLATION AT 1.06 μ IN THE SERIES

$\text{Na}_{0.5}\text{Gd}_{0.5-x}\text{Nd}_x\text{WO}_4$.
 G. E. Peterson and P. M. Bridenbaugh (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).
Applied Physics Letters, vol. 4, May 15, 1964, p. 173-175. 11 refs.

Discussion of laser action in a system in which the density of active ions is high. Laser action is observed at a wavelength of about 1.06 μ for compounds in the series $\text{Na}_{0.5}\text{Gd}_{0.5-x}\text{Nd}_x\text{WO}_4$, where the range of x is from 0.01 to 0.5. The linewidths are independent of concentration, but do sharpen with decreasing temperature. The concentration variation of the fluorescent lifetime of the $^4\text{F}_{3/2}$ state is determined at room temperature by a stroboscopic technique. The quantum efficiency of this state decreases rapidly with room temperature.

A64-19555

GIANT-PULSE LASER AND LIGHT AMPLIFIER USING VARIABLE TRANSMISSION COEFFICIENT GLASSES AS LIGHT SWITCHES.

Georges Bret and Francois Gires (C. S. F., Département de Physique Appliquée, Orsay, Seine-et-Oise, France).
Applied Physics Letters, vol. 4, May 15, 1964, p. 175, 176.
 Brief description of a giant-pulse laser and a light amplifier which employ glass whose light-transmission coefficient depends strongly on the intensity of the incident light for optical switching. The energy and duration of a ruby-laser pulse are measured for the laser operating with both glass plate and Kerr cell optical switches.

A64-19556

LOCALIZED FLUID FLOW MEASUREMENTS WITH AN He-Ne LASER SPECTROMETER.

Y. Yeh and H. Z. Cummins (Columbia University, Columbia Radiation Laboratory, New York, N. Y.).
Applied Physics Letters, vol. 4, May 15, 1964, p. 176-178.
 Research supported by the Joint Services; NSF Grant No. GP-438; Grant No. DA-ARO-D-31-124-G380.

Description of a method for measuring the Doppler shifts in the Rayleigh scattered light from polystyrene spheres (0.557- μ diam.) suspended in water. An He-Ne laser spectrometer is used to

measure the Doppler shifts for spheres whose velocities are as low as 0.007 cm/sec. The laser beam is split by a beam splitter. The beam traversing one arm of an interferometer is SSB-modulated and acts as an optical local oscillator, while the other beam illuminates the scattering cell. The scattered radiation is focused and recombined with the local oscillator beam at the cathode of a photomultiplier, and the beat signal is processed electronically with an instrumental resolution of about 10 cps. The spheres produce a line-broadening of about 10 cps at 30° owing to diffusion. This corresponds to a minimum detectable velocity of 0.004 cm/sec.

A64-19557

CONTINUOUS VISIBLE LASER ACTION IN SINGLY IONIZED ARGON, KRYPTON, AND XENON.

E. I. Gordon, E. F. Labuda (Bell Telephone Laboratories, Inc., Murray Hill, N. J.) and W. B. Bridges (Hughes Aircraft Co., Hughes Research Laboratories, Malibu, Calif.).
Applied Physics Letters, vol. 4, May 15, 1964, p. 178-180. 6 refs.

Discussion of continuous laser action at wavelengths from 4545 to 5287 Å in singly ionized argon, krypton, and xenon. To achieve continuous laser action with relatively modest currents, the lasers, using Brewster windows and external dielectric mirrors, are constructed of small-bore quartz tubing. The threshold levels for laser oscillation at several visible wavelengths are reported, and the behavior of the laser action at 4880 Å is studied.

A64-19559

LASER OSCILLATIONS IN Nd-DOPED YTTRIUM ALUMINUM, YTTRIUM GALLIUM AND GADOLINIUM GARNETS.

J. E. Geusic, H. M. Marcos, and L. G. Van Uitert (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).
Applied Physics Letters, vol. 4, May 15, 1964, p. 182-184.
 Contract No. DA-36-039-AMC-02333(E).

Description of the continuous operation of a yttrium-aluminum laser pumped at room temperature with a tungsten lamp. In addition, pulsed oscillations in Nd-doped yttrium-gallium and gadolinium-gallium garnets are studied at 300°K. The pulsed behavior of the various systems is observed by inserting a laser rod into a helical xenon flash-lamp. In the continuous oscillation experiments, the laser crystal is placed at one focus of an elliptical cylinder, and an Hg lamp or quartz-iodine-tungsten lamp is placed at the other focus. It is felt that, with optimization of crystal quality and Nd concentration, further reductions of threshold levels will be obtained.

A64-19748

THE COUPLED-CAVITY TRANSMISSION MASER-ANALYSIS.

T. R. O'Meara (Hughes Aircraft Co., Research Laboratories, Malibu, Calif.).
IEEE Transactions on Microwave Theory and Techniques, vol. MTT-12, May 1964, p. 336-348. 23 refs.

Discussion of an analysis of a maser amplifier structure developed at Hughes Research Laboratories and consisting of a cascade of iris-coupled $\pi/2$ -cavities with isolators. Starting from the basic media susceptibility, narrow-band equivalent networks and matrix representations are derived for maser and isolator cavities. A rational function approximation to the overall gain functions is thereby derived by matrix methods. From one viewpoint, the overall amplifier may be regarded as a negative-resistance inverse-feedback amplifier. The key design parameter is shown to be the isolator round-trip attenuation. Excess isolation yields an overly rounded gain-frequency characteristic, while deficient isolation yields a characteristic with excess ripple or instability in the extreme cases. The feedback effects associated with intermediate "optimum" values of isolation reduce the effective gain per cavity below the normal gain of a single cavity, but in return one obtains a reduced gain sensitivity which may be reduced to a value comparable to or lower than that of the pure traveling-wave maser.

A64-19749

THE COUPLED-CAVITY TRANSMISSION MASER-ENGINEERING DESIGN.

F. E. Goodwin, J. E. Kiefer, and G. E. Moss (Hughes Aircraft Co., Research Laboratories, Malibu, Calif.).
IEEE Transactions on Microwave Theory and Techniques, vol. MTT-12, May 1964, p. 349-358. 14 refs.

Description of the experimental design of an X-band microwave maser amplifier which uses a new type of slow-wave circuit. The slow-wave circuit consists of a cascade of iris-coupled ruby resonators separated by garnet isolators. This unit provides significant reduction in size and weight over previously reported maser slow-wave circuits. The microwave properties of the solid ruby resonator are treated in detail, and the passive bandwidth of the single transmission cavity and its relation to the iris susceptance are shown. Experimental techniques involved in obtaining and measuring precise iris susceptance are presented. A step-by-step procedure for designing an amplifier having a given gain and tuning range is also presented. Typical performance characteristics include a gain of 30 db, instantaneous bandwidth of 25 Mc, and a noise temperature of 15°K. An electronic tuning range of 200 Mc has been achieved in one configuration with a 20-db gain and a 25-Mc bandwidth. The weight of the maser and dewar flask unit, filled with 6 liters of helium for 24 hours of operation, is less than 40 lb. The design of the dewar flask enables the cryogenic system to work over a wide range of vertical angles, thus facilitating the use of the maser at the feed of a large steerable antenna.

A64-19876

THEORY OF AN OPTICAL MASER.

Willis E. Lamb, Jr. (Yale University, New Haven, Conn.).
 (International Conference on Quantum Electronics, 3rd, Paris, France, Feb. 1963.)
Physical Review, 2nd Series, vol. 134, June 15, 1964, p. A1429-A1450. 22 refs.

USAF-supported research.

Theoretical investigation of the operation of multimode maser oscillators. A high-Q multimode cavity is considered in which there is given a classical electromagnetic field acting on a material medium which consists of a collection of atoms described by the laws of quantum mechanics. The effect of the electromagnetic field on the atoms in the cavity is to produce a macroscopic electric polarization of the medium. This acts as a source for the electromagnetic field, in accordance with Maxwell's equations. The calculations include nonlinear effects. Among the results obtained are the threshold conditions, the single-mode output as a function of cavity tuning, the production of combination tones, and population pulsations. A more approximate discussion of maser action using rate equations is also given in which the concept of "hole burning" plays a role.

A64-19921

DETERMINATION OF THE VELOCITY OF LIGHT USING THE LASER AS A SOURCE.

Douglas Sinclair and M. Parker Givens (Rochester, University, Institute of Optics, Rochester, N. Y.).
Optical Society of America, Journal, vol. 54, June 1964, p. 795-797.

Contract No. AF 19(628)-465.

Measurements of the velocity of light using a continuously operating gas laser as the source. The He-Ne laser, operating in the red (6328 \AA), produces several closely spaced but sharp spectral lines. Two of these lines are isolated and directed through a mirror arrangement to a photomultiplier. The output is then fed to a radio receiver (tuned to respond only to beat frequencies of 150 and 300 Mc) where the beat signal is amplified and measured in a final detector circuit. This self-modulation obviates the need for the usual toothed wheels, rotating mirrors, etc. Two independent runs give $c = 2.992$ and $c = 2.993 \times 10^8 \text{ m/sec}$, where the last figures are probably not significant. These results differ from each other and from the accepted value ($\approx 2.998 \times 10^8 \text{ m/sec}$) by less than 1%, but it is believed that greater accuracy may be obtained with more refined frequency- and distance-measuring techniques.

A64-19933

THEORY OF INTERMODULATION AND HARMONIC GENERATION IN TRAVELING-WAVE MASERS.

E. O. Schulz-DuBois (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).
IEEE, Proceedings, vol. 52, June 1964, p. 644-656. 10 refs.
 Contract No. DA 36-039-SC-85357.

Development of a quantitative theory for traveling-wave maser intermodulation using both the density matrix formalism and the Bloch equations of motion. Under high power conditions, a nonlinear response in the spin system of a maser is predicted by an analysis based on either of the above approaches. The coupling of the nonlinearities to the traveling-wave maser circuit is considered, and the measurable power output at intermodulation and second harmonic frequencies is computed. For a typical traveling-wave maser with ruby maser material and a comb slow-wave structure, the computation yields power levels that are below noise under most operating conditions of masers used as low-noise receiver preamplifiers.

A64-19934

MEASUREMENT OF INTERMODULATION AND A DISCUSSION OF DYNAMIC RANGE IN A RUBY TRAVELING-WAVE MASER.

W. J. Tabor, F. S. Chen, and E. O. Schulz-DuBois (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).
IEEE, Proceedings, vol. 52, June 1964, p. 656-663. 7 refs.
 Contract No. DA-36-039-SC-89169.

Measurement of intermodulation in a ruby traveling-wave maser similar to the one developed for project Telstar. The power level at frequency $2f_2 - f_1$ is measured when strong signals at frequencies f_1 and f_2 are applied to the maser. In agreement with theoretical predictions, the intermodulation power level is found to be extremely weak. Results of the measurement can be expressed as $P(2f_2 - f_1) = 2P(f_2) - P(f_1) - 95$, where $f_1 = 4110 \text{ Mc}$, $f_2 = 4140 \text{ Mc}$, and the powers are measured in dbm. The dynamic range of the traveling-wave maser is described with emphasis on the gain saturation and intermodulation behavior.

A64-19939

THE LASER INTERFEROMETER - APPLICATION TO PLASMA DIAGNOSTICS.

J. B. Gerardo and J. T. Verdeyen (Illinois, University, Dept. of Electrical Engineering, Urbana, Ill.).
IEEE, Proceedings, vol. 52, June 1964, p. 690-697. 10 refs.
 Contracts No. AF19(604)-3307; No. SC87232.

Discussion of a laser interferometer employing a reference cavity with spherical mirrors. Its sensitivity is greater than that of a similar interferometer with planar mirrors because the closely spaced normal modes with nonzero transverse indices can be resolved in the former but not in the latter. The optimum geometrical conditions of both the laser resonant structure and the reference arm are considered. It is shown that the geometry of each cannot be chosen independently of the other due to the fact that the laser output usually consists of many frequencies within the Doppler-broadened laser transition. Sensitivity limitations and some experimental measurements of electron densities in gaseous plasmas are also discussed.

A64-19944INJECTION-LUMINESCENCE PUMPING OF A $\text{CaF}_2 : \text{Dy}^{2+}$ LASER.

S. A. Ochs and J. I. Pankov (Radio Corporation of America, RCA Laboratories, Princeton, N. J.).
IEEE, Proceedings, vol. 52, June 1964, p. 713, 714.
 Research supported by the Radio Corporation of America; Contract No. NAS 8-5219.

Note on the successful pumping of a $\text{CaF}_2 : \text{Dy}^{2+}$ laser by means of injection luminescence. The $\text{GaAs}_x\text{P}_{1-x}$ diodes are used at pumped-helium temperatures to provide effective optical pumping for durations of up to 0.2 sec. The laser rod and surrounding diodes are immersed in liquid helium cooled slightly below the lambda point. The output of the laser is viewed through two windows by an InAs detector. Current is passed through the diodes in manually triggered

single pulses whose amplitude and duration can be adjusted. As the pumping current is increased, the lasing delay is reduced, and the average pulse height and pulse density are increased.

A64-19945

CW OPTICAL MASER ACTION UP TO 133 μ (0.133 MM) IN NEON DISCHARGES.

C. K. N. Patel, W. L. Faust, R. A. McFarlane, and C. G. B. Garrett (Bell Telephone Laboratories, Inc., Murray Hill, N.J.). IEEE, Proceedings, vol. 52, June 1964, p. 713. 6 refs.

Note on 14 new maser transitions in a pure neon discharge ranging from 50 to 133 μ . The maser structure used is similar to that reported previously by the authors, but the discharge-tube diameter is larger in the present case to keep the diffraction losses small at longer wavelengths. The wavelengths of the oscillating transitions are measured with a 250-mm monochromator. The order separation between different orders of the grating is achieved through the use of various transmission filters such as sapphire and impregnated polyethylene.

A64-19947

NOVEL LASER Q-SWITCHING MECHANISM.

J. L. Wentz (Westinghouse Electric Corp., Aerospace Div., Defense and Space Center, Baltimore, Md.).

IEEE, Proceedings, vol. 52, June 1964, p. 716, 717.

Note on the use of potassium dihydrogen phosphate (KDP) for Q-switching lasers. The Q-switch mechanism consists of two KDP crystals operating as an optical shutter. The laser beam does not have to pass through transparent electrodes, and the mechanism operates at halfwave voltages that are substantially less than 1000 volts. The device considered here can also be employed as an optical amplitude modulator.

A64-19950

ELECTRO-OPTIC FREQUENCY MODULATION IN OPTICAL RESONATORS.

Ammon Yariv (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Electronics Research Laboratory, Palo Alto, Calif.). IEEE, Proceedings, vol. 52, June 1964, p. 719, 720. 7 refs.

Discussion of some possible applications of the electron-optic effect. Frequency modulation of lasers, longitudinal-mode suppression in lasers, and laser frequency stabilization are considered. These applications are based on control of the internal feedback conditions in an optical resonator. They provide an electrical, rather than an electromechanical or magnetomechanical means of tuning the resonator.

A64-19952

GAS BREAKDOWN CRITERION FOR PULSED OPTICAL RADIATION.

Richard G. Tomlinson (Ohio State University, Dept. of Electrical Engineering, Antenna Laboratory, Columbus, Ohio). IEEE, Proceedings, vol. 52, June 1964, p. 721, 722.

Contract No. AF 33(657)-10824.

Development of a breakdown criterion for a Q-switched gas laser. It is stated that the applicable breakdown criterion, when a particular gas mixture at a given pressure and ambient electron density is exposed to radiation of a particular wavelength, intensity, and pulse duration, is that criterion which yields the smaller value for the critical density of free electrons.

A64-19954

TRIANGULAR INJECTION LASERS.

J. C. Marinace, A. E. Michel, and M. I. Nathan (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N.Y.).

IEEE, Proceedings, vol. 52, June 1964, p. 722, 723.

Brief note on injection lasers which are fabricated in the shape of equilateral triangles. Some of these lasers exhibit highly directional beams and a rapid increase in quantum efficiency at threshold, characteristic of Fabry-Perot lasers. Others are nondirectional and have no increase in quantum efficiency at threshold. Their spectrum is similar to nondirectional rectangular parallelepipeds with four cleaved sides. The triangular structures are cleaved diffused GaAs wafers.

A64-20056

ABSOLUTE SCATTERING FUNCTIONS AND TRANSMISSION VALUES FOR INTERPRETING LASER LIGHT SCATTERING IN THE MESOSPHERE.

E. P. Palmer (Utah, University, Dept. of Electrical Engineering, Salt Lake City, Utah) and W. G. Zdunkowski (Utah, University, Dept. of Meteorology, Salt Lake City, Utah).

Journal of Geophysical Research, vol. 69, June 1, 1964, p. 2369-2377. 24 refs.

NSF-supported research.

Calculations of the absolute scattering functions for Rayleigh and Mie-particle scattering for laser light of 7000 \AA , particle radii ranging from 0.056 to 1.67 microns, and indices of refraction of 1.330 (water) and 1.500 (silicates). Transmission values for a molecular atmosphere and an atmosphere containing particles are presented and night airglow background is estimated. The particle concentrations necessary for Mie scattering to equal Rayleigh scattering are given for various scattering angles and particle sizes. The application of the calculations to systems for measuring particle concentrations by light scatter is discussed.

A64-20351

APPLICATION OF RESONANCE COOPERATION OF RARE-EARTH IONS Nd^{3+} AND Yb^{3+} TO LASERS ($\text{Na}_0.5\text{RE}_0.5\text{WO}_4$).

G. E. Peterson and P. M. Bridenbaugh (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

Applied Physics Letters, vol. 4, June 15, 1964, p. 201, 202. 9 refs.

Note on the application of resonance phenomena to provide an increase in the effective number of pumping bands by the coupling of two dissimilar ions. For an excited A-ion to exchange energy nonradiatively with an unexcited B-ion, it is necessary that an energy gap downward from state M match a gap from the ground state in ion B. The gap from M need not necessarily be to the ground state. Exchange to ion B can also take place employing a gap in B not involving the ground state, provided that in the experiment the lower level of the B-gap be populated. Some coupling must exist between A and B. Because long-range interactions between rare earths are known, it is felt that electrostatic couplings play a significant role. As an example of an exchange process, the compound $\text{Na}_0.5\text{Cd}_0.46\text{Nd}_0.02\text{Yb}_0.02\text{WO}_4$, where Nd and Yb are resonance-coupled is briefly discussed.

A64-20352

NONRADIATIVE ENERGY EXCHANGE AND LASER OSCILLATION IN Yb^{3+} -, Nd^{3+} -DOPED BORATE GLASS.

A. David Pearson and S. P. S. Porto (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

Applied Physics Letters, vol. 4, June 15, 1964, p. 202-204. 7 refs.

Discussion of laser action in borate glasses doped with Nd^{3+} and Yb^{3+} ions. The glasses used contained 20 mole % calcium oxide, 10 mole % lithium oxide, and 70 mole % boron oxide and are refined to a homogeneous, bubble-free condition. Cylindrical rods are ground from the glass, polished as spherical mirror resonators, and silvered to give zero % transmission at one end and 2% at the other. Most of the laser experiments are carried out at 77°K by inserting the glass rods into a helical flashlamp enclosed in a cylindrical aluminum reflector, the whole apparatus being contained in a liquid nitrogen dewar flask. The laser radiation is focused onto the slit of a grating spectrometer having a photomultiplier as its detector. The wavelength of excitation of the laser action of three differently doped glasses is determined through the use of sharp cut-off filters placed between the flashlamp and rods, which are located outside of the flashlamp.

A64-20354LATTICE ENERGY TRANSFER AND STIMULATED EMISSION FROM $CeF_3:Nd^{3+}$

J. R. O'Connor (Massachusetts Institute of Technology, Lexington, Mass.) and W. A. Hargreaves (Optovac, Inc., North Brookfield, Mass.).

Applied Physics Letters, vol. 4, June 15, 1964, p. 208, 209. 7 refs. USAF-supported research.

Description of some of the laser properties of single crystals of CeF_3 , in particular, the transfer of lattice energy to stimulate emission from $CeF_3:Nd^{3+}$. Excitation experiments are performed on crystals containing 0.1 at. % Nd, fabricated into cylindrical etalons. The end faces are parallel, silvered, and flat to within $1/4$ of a wavelength. Optical pumping is accomplished by using three flashlamps, and the emission is monitored by a photomultiplier tube through an interference filter. Laser and flashlamp intensity signals are displayed as functions of time.

A64-20605

PHONON MASER PICTURE OF ACOUSTIC AMPLIFICATION - A SIMPLE EXAMPLE.

Harold N. Spector (Illinois Institute of Technology, Research Institute, Physics Div., Chicago, Ill.).

Philosophical Magazine, 8th Series, vol. 9, June 1964, p. 1057, 1058.

Presentation of a simple calculation of the absorption coefficient of the acoustic wave to permit the phenomenon of acoustic amplification to be regarded quantitatively as a stimulated emission of phonons. It is considered that this picture of a phonon maser is very useful from a conceptual point of view.

A64-20918

IMPURITY STATES IN SEMICONDUCTING MASERS.

H. J. Zeiger (Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.).

Journal of Applied Physics, vol. 35, June 1964, p. 1657-1667. 18 refs.

Development of a formalism for the computation of negative conductivities for inverted populations involving impurity states in semiconductors. General expressions are derived for the following classes of systems: (1) transitions between states belonging to the same band edge, (2) direct transitions between states belonging to different band edges, and (3) indirect transitions between states belonging to different band edges. The expressions for negative conductivities are simplified by making use of the effective mass approximation. The results are applied to an example of each of the three classes of processes, where class (2) is represented by a model of the GaAs diode laser. For this model it is found that, at low temperatures, with an acceptor concentration of $\sim 10^{18}/cm^3$ and an effective acceptor radius of $\sim 20 \text{ \AA}$, population inversion of donor states relative to acceptor states yields a greater negative conductivity than inversion of donor states relative to the valence band. A brief discussion of diode-laser threshold conditions is presented.

A64-20919

PULSE PROPAGATION IN A LASER AMPLIFIER.

James P. Wittke (Radio Corporation of America, RCA Laboratories, Princeton, N. J.) and Peter J. Warter (Princeton University, Electrical Engineering Dept., Princeton, N. J.).

Journal of Applied Physics, vol. 35, June 1964, p. 1668-1672. 8 refs.

Discussion of pulse propagation in maser-type traveling-wave amplifiers with a homogeneously broadened transition on the basis of formalism analogous to the Bloch equation. Phenomenological dephasing and recovery times are defined, and a linear (nonsaturable) loss mechanism is included. The numerical calculations presented are limited to the case of negligible excitation during the time it takes a pulse to pass. For the case in which pulses are allowed to grow until the amplifier is saturated, the accompanying

steady-state pulses are found to have a unique shape and an intensity that is independent of the initial pulse. The parameters of these steady-state pulses depend only on the ratio of the linear loss and gain coefficients. Steady-state pulses have a peak intensity that decreases monotonically from infinity to zero as the linear loss coefficient varies from zero to the gain coefficient, while the pulse width correspondingly varies from zero to infinity, and the pulse energy varies from a finite value to zero. Steady-state pulses propagate at a velocity less than that of the small signal velocity in the medium.

A64-20920

SIZE-DEPENDENT SPONTANEOUS ENERGY LOSS IN LASERS DUE TO SELF-STIMULATED EMISSION.

Tom Waite (North American Aviation, Inc., Science Center, Canoga Park, Calif.).

Journal of Applied Physics, vol. 35, June 1964, p. 1680-1682.

Analysis showing that large traveling-wave laser amplifiers (or a series of smaller ones) when pumped to a significant degree of population inversion undergo decay via: (1) natural spontaneous emission of radiation from individual excited atoms, and (2) a size-dependent decay due to self-amplification of the spontaneously emitted radiation which passes through a large fraction of the amplifier length before escaping. This latter effect has a definite size threshold near which the decay rate changes several orders of magnitude. The decay rate is roughly independent of size except near the threshold.

A64-20996

LONG DISTANCE INTERFEROMETRY WITH A He-Ne LASER.

F. T. Arecchi and A. Sona (Laboratori C.I.S.E., Milan, Italy).

Nuovo Cimento, Serie Decima, vol. 32, May 16, 1964, p. 1117-1121. 5 refs.

Research supported by the Consiglio Nazionale delle Ricerche.

Presentation of preliminary results of a long-distance interferometry experiment, where the source is a He-Ne laser working at the 6328 \AA transition in single-mode operation. It is shown that an ordinary visible laser is a source suitable for interferometry over path differences larger than 120 m. An integral plot shown for a unit time of 0.1 sec (total time 51.2 sec) and for lengths of both arms of around 50 cm yields information both on the long-term stability of the system considered and on the number of wavelengths corresponding to a calibrated movement.

A64-21002AN OPTICALLY PUMPED ^{87}Rb LASER OSCILLATOR.

P. Davidovits (Columbia University, Radiation Laboratory, New York, N. Y.).

Applied Physics Letters, vol. 5, July 1, 1964, p. 15, 16.

Joint Services-supported research.

Description of laser oscillations observed in optically pumped ^{87}Rb at the ground state hyperfine transition frequency ($\sim 6835 \text{ Mc}$). The ^{87}Rb was placed with nitrogen buffer gas at a pressure of 11 torr in a glass cell designed to fit a tuned microwave cavity. The system was magnetically shielded, and the magnetic field on the system was reduced to below 100 \mu Gauss . In this way, the various hyperfine Zeeman transitions are made to overlap, and stimulated emission from atoms in the $F = 2$, $m_F = \pm 1$ levels combines with the emission from atoms in the $F = 2$, $m_F = 0$ level to produce high gain. The characteristics of the resulting self-sustained laser oscillation are discussed.

A64-21058

INTERACTION OF VERY INTENSE RADIATION FIELDS WITH ATOMIC SYSTEMS.

Oldwig von Roos (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.).

Physical Review, Second Series, vol. 135, July 6, 1964, p. A43-A50. 12 refs.

Contract No. NAS 7-100.

Presentation of a method for analyzing multi-phonon radiation processes in first- or second-order perturbation theory. The theory is applied to the interaction of an atomic electron with a very intense linearly polarized laser beam. It is found that, under certain approximations, induced radiation will occur at all harmonics of the fundamental laser frequency. The intensity distribution of this radiation is symmetric about the axis of polarization of the primary beam and is peaked at an angle of 45° with respect to direction of propagation of the secondary radiation. This angle markedly shifts toward 0° for higher harmonics. The transition probabilities are high enough to make the effect readily noticeable.

A64-21214**THE OPTO-ACOUSTIC MASER EFFECT.**

V. R. Nagibarov and U. Kh. Kopvillem (Academy of Sciences, Physico-Technical Institute, Kazan, USSR).
(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 45, Dec. 1964, p. 2006-2008.)
Soviet Physics - JETP, vol. 18, May 1964, p. 1377, 1378. 8 refs. Translation.

Analytical investigation of a multiple-quantum maser effect by which phonons are generated directly from photons, rather than from magnons, as by single quantum effects. This opto-acoustic effect is illustrated and is noted as being a promising mechanism for opening the millimeter and submillimeter regions of the electromagnetic spectrum and for producing hypersonic vibrations and microwave frequencies up to the Debye frequency.

A64-21283

LINE STRENGTHS FOR NOBLE-GAS MASER TRANSITIONS; CALCULATIONS OF GAIN/INVERSION AT VARIOUS WAVELENGTHS. W. L. Faust and R. A. McFarlane (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).
Journal of Applied Physics, vol. 35, July 1964, p. 2010-2015. 28 refs.

Derivation of relative line strengths for s-p, p-d, and d-f transitions of Ne, Ar, Kr, and Xe by the method of Koster and Stutz, under the assumption of the j-L coupling scheme of Racah. When the relative strengths are given a common denominator, a set of rules for strong lines becomes apparent, similar to rules which have been noted for L-S coupling. For comparison with experiment, several sets of Ne lines are considered, each set having one specific initial and one final configuration. For the higher L values (p-d and d-f) the lines found to give oscillation are almost exclusively the lines with large relative strengths. The absolute line strengths S are then calculated in the Coulomb approximation of Bates and Damgaard; only transitions between two excited states are considered. The inversion quantity is said to be a population difference between elementary quantum states.

A64-21367**LASER EFFECT ON MERCURY VAPOR IN AN He-Hg MIXTURE [EFFET LASER SUR LA VAPEUR DE MERCURE DANS UN MELANGE He-Hg].**

Marc Armand and Philippe Martinot-Lagarde (Compagnie Générale de Télégraphie sans Fil, Laboratoires, Corbeville, Seine-et-Oise, France).
Académie des Sciences (Paris), Comptes Rendus, vol. 258, no. 3, Jan. 20, 1964, p. 867, 868. In French.

Experimental obtainment of the laser effect on two mercury bands at 1.53 and 1.81 μ , in a mixture of helium and mercury, by pumping with an electric discharge. The classic experimental device used is outlined, and the result obtained is interpreted. It is stated that the spectrograph used permits the measurement of the wavelength at approximately 0.01 μ . The two wavelengths measured are 1.53 and 1.81 μ . The optic gain of the former is higher than 20% that of the latter band appears weaker.

A64-21430**ELLIPTICAL HEAD FOR LIQUID LASER RESEARCH.**

Erhard J. Schimitschek and Adolph L. Lewis (U. S. Navy, Electronics Laboratory, San Diego, Calif.).
Review of Scientific Instruments, vol. 35, July 1964, p. 911, 912.

Brief description of a laser head for liquid laser materials, which uses an elliptical configuration and which enables observation of the liquid in situ. Construction details of the laser head are shown diagrammatically. Two cylinder-halves hinged together along one side form a cavity of elliptical cross section with a major and minor axis of 3.750 in. and 3.438 in., respectively. The two end plates supporting all the necessary feedthroughs are secured to the lower cylinder-half. The elliptical shape of the two aluminum cylinder-halves was produced on a milling machine with a 1-in. diam. tool cutting in small increments along the cylinder axis. The laser liquid, contained in a capillary quartz cell and surrounded by a double-walled evacuated quartz Dewar flask, is located at one of the focal lines.

A64-21618**RADAR APPLICATIONS OF THE LASER.**

Durwood L. Creed (USAF, Systems Command, Rome Air Development Center, Griffiss AFB, N. Y.).

IN: NATIONAL WINTER CONVENTION ON MILITARY ELECTRONICS, 5TH, LOS ANGELES, CALIF., FEB. 5-7, 1964, PROCEEDINGS. VOLUME 3.

Convention sponsored by the Professional Technical Group on Military Electronics, Institute of Electrical and Electronics Engineers.

Edited by R. F. Lander.

North Hollywood, Western Periodicals Co., 1964, p. 17-7 to 17-14.

Discussion of the relationship between radar detection factors and carrier frequency. It is concluded that for a given amount of energy expended, the maximum amount of target information extractable is a direct function of the radar carrier frequency. This is seen as an argument for laser application. The applicability as well as the limitations of laser radar are studied. The principal classes of lasers are noted, and unique applications are presented.

A64-21657**SPECTROSCOPIC PROPERTIES OF ACTIVATED LASER CRYSTALS. I.**

P. Görlich, H. Karras, G. Kötitz, and R. Lehmann.

Physica Status Solidi, vol. 5, no. 3, 1964, p. 437-461. 75 refs.

Presentation covering the theoretical aspects of laser action and the spectroscopic properties of ions of transition metals, of the lanthanide and actinide groups in conjunction with the different host crystals. The geometry and excitation of laser resonators of activated crystals are discussed. The theory of spontaneous transition, induced transition, optical excitation, and laser condition is covered. The main requirements for low threshold values for the onset of laser action at a fixed emission frequency are considered. Ions of the lanthanides and actinides, alkaline earth fluorides, various tungstates and molybdates, and the transition metals (Cr, Ni, Co) in sapphire and other host crystals are then discussed as activators. Spectroscopic data on absorption, spontaneous fluorescence, and stimulated emission are given.

A64-21705**SOLID STATE LASER MATERIALS.**

Morris Katzman (U. S. Army, Electronics Research and Development Laboratories, Fort Monmouth, N. J.).

IN: MATERIALS SCIENCE AND TECHNOLOGY FOR ADVANCED APPLICATIONS; PROCEEDINGS OF THE GOLDEN GATE MATERIALS CONFERENCE, SAN FRANCISCO, CALIF., FEB. 13-15, 1964. VOLUME 2.

Conference sponsored by the American Society for Metals.

Berkeley, Calif., American Society for Metals, 1964, p. 333-350.

Brief discussion of the more important optically pumped laser (optical maser) solids. The properties of the laser solid are discussed, particularly those relevant to laser operations. The topics discussed include laser resonant structures, laser resonator and fluorescent linewidth, population inversion, material parameters, laser-crystal growth, laser operation, and laser applications.

A64-21992

EVALUATING LIGHT DEMODULATORS.

D. E. Caddes and B. J. McMurtry (Sylvania Electric Products, Inc., Sylvania Electronic Systems, Electronic Defense Laboratories, Mountain View, Calif.).

Electronics, vol. 37, Apr. 6, 1964, p. 54-61. 39 refs.

Presentation of a method for comparing various designs of photodetectors for laser communications or radar systems. The operation of photodetectors is considered in terms of three criteria: quantum efficiency of the photo process, current multiplication factor, and equivalent load resistance. The proposed comparison approach is then applied to some of the major types of detectors. It is concluded that for direct detection of amplitude-modulated light, the photodetector sensitivity may be characterized by $M^2\gamma^2/R_{eq}$. The high current gain of photomultiplier tubes therefore makes them the most sensitive detectors of low-frequency modulation for optical carriers in the visible range where good photo-emission quantum efficiencies are possible. Available photomultipliers cannot detect microwave-frequency AM. The most sensitive broadband detector for the visible spectrum is the traveling-wave phototube, which has R_{eq} in the megohm range over octave bandwidths at microwave frequencies. For detection in the infrared regions, the semiconductor photodiode is the most sensitive AM detector, but junction capacitance makes a trade-off necessary between bandwidth and R_{eq} . Bulk photoconductors have better inherent bandwidth capability, but very low R_{eq} . For CW microwave-frequency systems, the same two photodetectors, the traveling-wave phototube, and the semiconductor photodiode are found to be of practical importance.

A64-21997

A NOTE ON THE RESONANT MODES AND SPATIAL COHERENCY OF A FABRY-PEROT MASER INTERFEROMETER.

G. J. Fan.

IBM Journal of Research and Development, vol. 8, July 1964, p. 335-337.

Analysis of the case of a Fabry-Perot cavity with light impinging on one end while the field distribution on the other end is observed. It is shown that if one starts with a wave that can be expanded into the modes of the integral operator, and if the medium in the cavity is passive, more than one mode may be observed at the other end although the amplitude of the dominant mode can be much greater than that of the other modes. It is further shown that if there is present an active medium with sufficient gain there will be only a single mode, and the single mode is necessary and sufficient for complete spatial coherency.

A64-21998

ANALYSIS OF A NONDEGENERATE TWO-PHOTON GIANT-PULSE LASER.

R. L. Garwin.

IBM Journal of Research and Development, vol. 8, July 1964, p. 338-340; Discussion, p. 340.

Equations for the photon population, development of the giant pulse, decay, and priming conditions in an alternative to the proposed two-photon laser of Sorokin and Braslau. It is shown that a system of ions N_B in a cavity resonant at two frequencies ν_A and ν_C such that $\nu_A + \nu_C = \nu_B$ may be primed at ν_A . The relaxation of the requirement of Sorokin and Braslau that $\nu_B = 2\nu_A$ is said to: (1) allow the use of metastable levels ν_B such that $\nu_B \gg \nu_A$ and thus makes available high-intensity laser output in a new short-wavelength range; (2) allow the production of new laser lines in addition to the

amplification of known ones; (3) ease substantially the problem of designing a system to exhibit the unique fast rise-time characteristics of the multiple-photon laser; and (4) allow the ready production of difference frequencies from the interaction, in a suitable nonlinear medium, of the automatically simultaneous giant pulses.

A64-22036

THEORY OF THE ELECTRICAL BREAKDOWN OF GASES BY INTENSE PULSES OF LIGHT.

J. K. Wright (Central Electricity Research Laboratories, Leatherhead, Surrey, England).

Physical Society, Proceedings, vol. 84, July 1964, p. 41-46. 7 refs.

Presentation of the theory of the type of gas breakdown caused by the intense electromagnetic radiation of focused laser beams. The mechanism analyzed is that in which an electron acquires energy from the radiation field by inverse bremsstrahlung absorption. When it has gained sufficient energy, the electron collides inelastically with a gas atom. In some cases this will cause ionization; but in most cases, the atom will be excited to a higher level. Photo-ionization by the absorption of a number of photons from the light pulse rapidly ensues. In this way the electron population multiplies exponentially. It is noted that there is reasonable agreement between this theory and previously published experimental results.

A64-22215

DISTRIBUTION OF PUMPING RADIATION DENSITY IN A LASER CRYSTAL.

Iu. A. Anan'ev and E. A. Korolev.

(Optika i Spektroskopiia), vol. 16, Apr. 1964, p. 702-704.)

Optics and Spectroscopy, vol. 16, Apr. 1964, p. 381, 382.

Translation.

A64-22363

FLASH AND CW METHODS FOR LASER POTENTIALITY MEASUREMENTS.

H. H. Theissing, P. J. Caplan, T. Ewanizky, and G. de Lhery (U.S. Army, Electronics Research and Development Laboratories, Fort Monmouth, N. J.).

Applied Optics, vol. 3, Aug. 1964, p. 951-955. 7 refs.

Experimental evaluation of the laser potentiality of $\text{CaF}_2:\text{Sm}^{2+}$ using a previously described method whereby data obtained by optical measurements on crystal slabs yield a figure of merit. The crystal employed in the experiment could also be lased, and thus a comparison between the predicted figure of merit is compared to the observed laser threshold. The measurements were carried out on two dark green rectangular crystals with square cross section. Both measurements were done in a helium dewar vessel provided with three side quartz windows. For the CW fluorescence measurements the side window was used. For the laser and flash fluorescence measurements, the pumping light was obtained by imaging the arc of a xenon lamp onto the crystal through the bottom window. Also described is a simple experimental arrangement for measuring $\int I_0 S_c d\lambda$ by the CW method (where I_0 is the intensity of the incident light beam, S_c the specific fluorescence, and λ is the wavelength).

A64-22369

LASER INTERFEROMETRY OF SMALL WINDOWS.

Robert M. Zoot (Litton Systems, Inc., Guidance and Control Systems Div., Woodland Hills, Calif.).

Applied Optics, vol. 3, Aug. 1964, p. 985, 986.

Brief description of a method for the complete optical testing of small mounted glass plates for surface flatness, homogeneity, and parallelism. The method employs a gas laser operating at 6328 \AA in the hemispherical mode which is aligned to the optical system of a small Michelson interferometer, a simple lens, and a projection screen. A schematic diagram showing the implementation of the technique is presented. Use of the method enables all necessary tests to be made, and the enlarged image produced on the screen can be simultaneously viewed by many observers.

A64-22563

THE POSSIBILITIES OF DEVELOPING AN OPTICAL MASER BY UTILIZING THE VIBRATION ENERGY OF GASES EXCITED BY ACTIVATED NITROGEN [SUR LES POSSIBILITES DE REALISATION D'UN MASER OPTIQUE UTILISANT L'ENERGIE DE VIBRATION DES GAZ EXCITES PAR L'AZOTE ACTIVE].

François Legay and Nicole Legay-Sommaire (Paris, Université, Laboratoire d'Infrarouge, Chimie Physique, Orsay, Seine-et-Oise, France).

Académie des Sciences (Paris), Comptes Rendus, vol. 259, no. 1, July 6, 1964, p. 99-102. 11 refs. In French.

Discussion of the problem, starting from consideration of an anticipated population inversion for high J-values of the rays of the branches "P" for the transitions $\Delta v = 1$ of CO, and calculation of the coefficient of maximal amplification. A semiquantitative discussion shows that it should be possible to achieve a total population inversion of two levels in the case of CO₂.

A64-22658

BROADBAND MASER UTILIZING THE CROSS MASER EFFECT.

Takashi Igarashi.

Radio Research Laboratories, Journal, vol. 11, Mar. 1964, p. 89-97. 5 refs.

Description of a chromium-doped rutile maser which utilizes the cross-relaxation effect to provide broadband amplification. The doped rutile has two nonequivalent Cr³⁺ ions in each unit cell, and the energy levels of these ions coincide for given axis directions. The overlapping of magnetic susceptibilities for these sites makes it possible to design a wide-band maser for a single-port cavity. The theoretical considerations for, and operation of such an amplifier are described.

A64-22678

LIFETIME OF HELIUM-NEON LASERS.

R. Turner, K. M. Baird, M. J. Taylor, and C. J. Van der Hoeven (National Research Council, Div. of Applied Physics, Ottawa, Canada).

Review of Scientific Instruments, vol. 35, Aug. 1964, p. 996-1001. 6 refs.

Experimental investigation of the factors affecting the lifetime of an RF-excited, internal reflector, helium-neon laser oscillating at 6328 Å. Studies were also made of tubes and with discharge conditions closely resembling those used in the lasers. Experiments are reviewed which determined factors influencing the rate of clean-up, and, in particular, of the relative clean-up of helium and neon. Using the results of the experiments, practical lasers of simple design were made having operating lifetimes of over 1000 hr. This performance is achieved by improving the reflectors and by adjusting discharge conditions and gas filling to optimum. Because of the initial rapid clean-up of neon, the filling should be rich in that gas. Thus a laser filled to 1.5 torr total pressure, helium to neon ratio 3:1, gas volume 30 cm³, 30 cm between reflectors, 4-mm bore discharge tube would operate at a power greater than 1/2 mw for over 1000 hr.

A64-22827

EXCITATION MECHANISMS OF POPULATION INVERSION IN CO AND N₂ PULSED LASERS.

P. K. Cheo and H. G. Cooper (Bell Telephone Laboratories, Inc., Whippany, N.J.).

Applied Physics Letters, vol. 5, Aug. 1, 1964, p. 42-44. 5 refs.

Review of spectral and temporal measurements of the spontaneous and stimulated radiation of CO and N₂ molecular gases with dc pulsed excitation, in order to investigate the basic excitation mechanisms responsible for population inversion in a pulsed gas laser. Two bands with heads at 6080 and 7753 Å were studied, the former belonging to the Ångström system of CO and the latter to the first positive system of N₂. The laser and spontaneous light signals were measured by a photomultiplier through a 1/2-m-grating spectrometer. Laser tubes of 4-, 6-, 10-, and 15-mm bore were used. The results, shown graphically, reveal a short laser pulse duration and a dependence of laser intensity on the applied electric

field of these pulsed gas lasers. These results are attributed to the electron energy and electron density distribution during gas breakdown.

A64-22828

DEPENDENCE OF THE RECOVERY TIME OF THE PULSED CARBON MONOXIDE LASER ON GAS PRESSURE AND TUBE BORE.

H. G. Cooper and P. K. Cheo (Bell Telephone Laboratories, Inc., Whippany, N.J.).

Applied Physics Letters, vol. 5, Aug. 1, 1964, p. 44-46.

Experimental investigation of the dependence, on various experimental parameters, of the dead time which follows an input pump pulse in a pulsed carbon monoxide laser using a double pulse excitation. A hardtube pulse modulator, used as the pump source, was double-triggered so that the spacing between two sequential pump pulses was continuously variable from 0.05 to 5 msec at repetition rates of 1 to 10 pps. The intensity of the second laser pulse was monitored as a function of the time separation of the double pulse. The results suggest that ion-electron recombination at the walls and in the volume is the principal recovery mechanism in the CO laser and that metastable effects are of secondary importance. The influence of CO dissociation on recovery is believed to be negligible. These conclusions are substantiated by measurements of spontaneous emission as a function of pulse spacing.

A64-22832

SWITCHING OF SEMICONDUCTOR REFLECTIVITY BY A GIANT PULSE LASER.

W. R. Sooy, M. Geller, and D. P. Bortfeld (Hughes Aircraft Co., Aerospace Group, Culver City, Calif.).

Applied Physics Letters, vol. 5, Aug. 1, 1964, p. 54-56.

Experimental investigation of the time development of semiconductor reflectivity under ruby giant pulse illumination. The laser uses a 65% output reflector, a 6.3-cm x 0.63-cm diam. ruby doped with 0.05% Cr, and a polished semiconductor in place of the usual 100% reflector. The low (40%) initial reflectivity of the semiconductor prevents oscillation until the rod gain is about 3 db, at which point normal laser action begins. The laser action increases the reflectivity of the semiconductor by inducing a high carrier concentration, and the output develops into a giant pulse. All the materials tested including Si, Ge, InP, InSb, and Ga(As, P, Sb) successfully operated as Q-switches. Silicon is the most reluctant material, usually yielding a string of normal laser pulses with an occasional interspace giant pulse.

A64-22834

STIMULATED RAMAN EMISSION AT 90° TO THE RUBY BEAM.

Jane H. Dennis and P. E. Tannenwald (Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.).

Applied Physics Letters, vol. 5, Aug. 1, 1964, p. 58-60. 12 refs.

Experimental investigation of 90° stimulated Raman emission in nitrobenzene. A 30-nanosec Q-switched ruby pulse of a few megawatts was focused by a 10-cm cylindrical lens into a cavity structure which had two side walls consisting of optical flats spaced 2.12 cm apart. The dielectric-coated flats are 99% reflecting at the first Stokes wavelength of nitrobenzene, are parallel to each other, and are placed at 90° to the forward ruby beam. When the ruby beam is fired into the cavity filled with nitrobenzene, stimulated Raman radiation is emitted at right angles to the forward direction. Theoretical interpretations of this effect are briefly discussed, as are possible applications, such as using the stimulated Raman effect to efficiently convert the energy from the nearly monochromatic output of a conventional laser into a coherent beam at a Raman-shifted wavelength having different, and possibly improved, spatial coherence properties.

A64-22835

SPATIAL DENSITY MEASUREMENTS IN FAST THETA-PINCH PLASMA BY LASER EXCITATION OF COUPLED INFRARED RESONATORS.

Robert F. Gribble, John P. Craig, and Arwin A. Dougal (Texas, University, Dept. of Electrical Engineering, Austin, Tex.). Applied Physics Letters, vol. 5, Aug. 1, 1964, p. 60-62. 7 refs. USAF-NSF-supported research.

Experimental investigation in which a space- and time-resolved plasma electron density in a Theta-pinch was measured by He-Ne laser excitation of coupled IR resonators at 3.39 μ . For 0.1-torr initial deuterium pressure, an electron density of $5.5 \times 10^{15}/\text{cm}^3$ was observed following super high-power plasma preheating. Resonator intensity modulation frequencies higher than 6 Mc, corresponding to an electron density variation of $10^{16}/\text{cm}^3/\mu\text{sec}$, were observed during fast magnetic compression to a peak of 11 kg in 3.5 μsec . The 6-Mc upper frequency limit for this coupled resonator system was due to the time response of the IR detectors, rather than to the laser Q. These results are seen to confirm the earliest considerations and expectations that the coherence, monochromaticity, and low beam divergence of IR lasers could be effectively utilized in a coupled resonator plasma-diagnostic technique.

A64-22844

APPLICATION OF THE STATISTICAL METHOD TO CALCULATION OF THE OPTICAL PROPERTIES OF LASERS.

B. I. Stepanov and V. P. Gribkovskii.

Uspekhi Fizicheskikh Nauk, vol. 82, Feb. 1964, p. 201-220.)

Soviet Physics - Uspekhi, vol. 7, July-Aug. 1964, p. 68-79. 27 refs. Translation.

[For abstract see Accession no. A64-16342 10-25]

A64-23033

THE ATOMIC HYDROGEN MASER.

C. Menoud, J. Racine, and P. Kartaschoff (Laboratoire Suisse de Recherches Horlogères, Neuchâtel, Switzerland).

Microtecnica, vol. 18, June 1964, p. 150-153. 6 refs.

Discussion of the maser as an extremely stable oscillator and of its potential as an accurate frequency standard. The experimental atomic hydrogen maser has a characteristic frequency of 1,420,405,751.5 \pm 0.3 cps; the uncertainty of \pm 0.3 cps is attributed to the magnetic field. The beam diameter is 2.5 mm, output power is 10^{-12} to 10^{-13} watts, and the SNR is 5 to 1 (detector beamwidth = 50 kc).

A64-23104

THE STIMULATED COMBINATION SCATTERING OF LIGHT [STIMULIROVANNOE KOMBINATSIONNOE RASSEIANIE SVETA].

V. A. Zubov, M. M. Sushchinskii, and I. K. Shubalov.

Uspekhi Fizicheskikh Nauk, vol. 83, June 1964, p. 197-222.

24 refs. In Russian.

Survey of investigations into the problem of stimulated combination scattering of light in view of the development of optical quantum generators (lasers). Experimental results obtained by systems with the scattering material located within and outside the resonator cavity are analyzed. Theories of the forced combination scattering - i.e., semiclassical and quantum theories - are developed. The design characteristics and principles of lasers based on the forced combination scattering of light are reviewed.

A64-23368

THE COHERENCE BRIGHTENED LASER.

R. H. Dicke (Princeton University, Palmer Physical Laboratory, Princeton, N. J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 35-53; Discussion, p. 54. 5 refs.

Description of a theoretical alternative to the stimulated-emission type of laser, first discussed briefly in a talk before the American Physical Society, Jan. 22, 1953, and later at the Fourth Congress of the International Commission of Optics held in Boston in 1956. It is a two-level laser in which the majority of the gas molecules are initially in the excited state. There are no reflecting mirrors, and the directivity of the superradiant transitions results from the pencil shape of the radiator. The closest analog to its operation is the Brown-Twist effect. Coherent radiation by multiple atom systems and coherence in large radiating systems are discussed. It is seen that the mirrorless laser is, in principle, capable of generating extremely short pulses of the order of 10^{-13} sec.

A64-23370

QUANTUM FLUCTUATIONS IN MASERS WITH LOSS.

W. H. Louisell (Stanford University, Stanford, Calif.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 65-69; Discussion, p. 69. 22 refs.

Study of the quantum fluctuations in a single mode of a cavity which is loosely coupled to a large number of loss oscillators (visualized as phonons) in thermal equilibrium at a positive temperature T_1 and simultaneously coupled to a large number of spin-1/2 particles in thermal equilibrium at a negative temperature $-|T_m|$. It is shown that the model will take into account the effects of a finite cavity Q or load in a self-consistent quantum mechanical fashion. The model is a generalization of that used by Senitsky and Schwinger.

A64-23373

SOME COHERENCE PROPERTIES OF NON-GAUSSIAN LIGHT.

L. Mandel (London, University, Imperial College of Science and Technology, Dept. of Physics, London, England).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 101-108; Discussion, p. 108, 109. 13 refs.

Study of departures from the Bose-Einstein counting distribution not introduced by disturbances in the medium. A photon beam from a typical thermal source is pictured as a mixture of a large number of photons in independent momentum-spin states. Because of the statistical independence of the numbers in different states, the ensemble distribution is represented as a set of points in a single photon phase space. It is shown that the radiation field can be described either quantum mechanically by a density matrix or classically by a fluctuating wave amplitude with specified statistical properties. Both descriptions are used, and differences between the fluctuation properties of maser light and light from ordinary thermal sources are pointed out. For a simple idealized maser beam, the difference is seen in terms of particle statistics. For more complex beams, the classical wave representation is found to be most convenient and is discussed in connection with higher-order correlation functions.

A64-23375

THE CONCEPT OF COHERENCE - ITS APPLICATION TO LASERS.

H. Modara (Hallicrafters Co., Chicago, Ill.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.
New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 121-137. 15 refs.

Redefinition and clarification of the concepts of time and space coherence. Attention is given to measurement of the coherent area and coherent length, the effect of time and space coherence on beamwidth, and the relation between spatial coherence and the spatial frequency spectrum. An operational definition of coherence is given based on expressions for the visibility and persistence of the fringe patterns obtained in suitable interferometer experiments.

A64-23376

A THEORY OF PUMPING BY INCOHERENT WAVES.

H. Dormont (Laboratoires d'Electronique et de Physique Appliquée, Paris, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 139-149.

Noncollision mathematical description of the maser effect. The model is a three-level (level 1 = ground state, level 2 = intermediate state, and level 3 = upper state) atomic system located inside an interferometer which acts as a high-Q cavity resonator. The frequency of the pumping electromagnetic wave (primary photon) is tuned to the difference $(1/2\pi)(\omega + \omega')$ between levels 3 and 1. The resonance frequency of the cavity is equal to the difference $\omega/2\pi$ between levels 2 and 1. A boson wave is emitted as a result of electronic transitions from level 3 to level 2 with the frequency $\omega'/2\pi$. This wave is thought of as a phonon wave operating like the idle circuit of a parametric oscillator. The model is said to overcome objections (mainly having to do with coherent effects) to the usual collision theory.

A64-23377

PARTIALLY COHERENT PROCESSES WITHIN AN OPTICAL MASER CAVITY.

Yoh-han Pao (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 151-157. 8 refs.

Quantum mechanical formulation of equations describing nonsteady-state optical maser processes for the fully coherent and fully incoherent cases. The limits of validity of the resulting expressions are obtained. Whether a coherent or incoherent description applies is seen to be determined by the line width of the fluorescence. The discussion follows the context of a specified initial state of inverted molecular population. The events of interest are those occurring from 10^{-9} to 10^{-6} sec after the establishment of the population inversion.

A64-23380

REMARKS ON THE RECEPTION OF COHERENT WAVES [REMARQUES SUR LA RECEPTION D'ONDES COHERENTES].

G. Pircher (Compagnie Française Thomson-Houston, Châtillon-sous-Bagneux, Seine, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 179-186. In French.

Space-time analysis of laser signal reception by a photodetector. Laws governing the emission probability and its fluctuations are reviewed and briefly discussed.

A64-23385

MASER AND SPIN-OSCILLATOR MAGNETOMETERS [MAGNETOMETRES A MASER ET A OSCILLATEURS DE SPIN].

P. Grivet, A. Blaquiére (Institut d'Electronique, Orsay, Seine-et-Oise, France), and G. Bonnet (Grenoble, Université, Grenoble, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 231-261. 64 refs. In French.

Review of the history, theory, and applications of magnetic resonance to the measurement of weak fields. The precision of the Packard-Varian method is compared with that of other techniques. Recent improvements in the Packard-Varian method are described. In this connection the weakness of the nuclear gyromagnetic constant γ_n is discussed along with the Thomson-Brown extension of the proton magnetometer to zero fields. Utilization of the Overhauser effect in nonmetals to circumvent the lack of continuity in the Packard-Varian method is discussed. Liquid-current masers and spin-coupling oscillators are described. Expressions for the ultimately attainable precision of masers and spin oscillators in frequency measurements are derived.

A64-23393

OPTIMIZATION OF THE SENSITIVITY OF A CESIUM VAPOR OPTICAL PUMPING MAGNETOMETER OF THE KASTLER TYPE

[OPTIMISATION DE LA SENSIBILITE D'UN MAGNETOMETRE A POMPAGE OPTIQUE (TYPE KASTLER) A VAPEUR DE CESIUM].

L. Malnar (Compagnie Générale de Télégraphie sans Fil, Département de Physique Appliquée, Corbeville, Seine-et-Oise, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 305-315. In French.

Discussion of the critical parameters in the construction and operation of an alkali vapor maser used to measure geomagnetic fields. The two principal difficulties are seen to be the smallness of the magnitudes to be measured in the presence of noise, high temperature, and vibration, and the lack of consistent knowledge concerning the energy levels involved. The theoretical limits of sensitivity are discussed. The chief sources of error are analyzed, including shot noise in the photoelectric cells, LF amplifier noise, and fluctuations in the subcircuits.

A64-23397

BEAM MASER SPECTROSCOPY AND APPLICATIONS.

K. Shimoda (Tokyo, University, Dept. of Physics, Tokyo, Japan).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 349-355. 7 refs.

Brief review of the theory and applications of molecular beams to LF spectroscopy. A device employing a four-level system for the generation and detection of submillimeter waves is reported under construction.

A64-23401

FOCUSING OF MOLECULAR BEAMS FOR MASERS WITH RING- AND SCREW-ELECTRODES.

G. Becker (Physikalisch-Technische Bundesanstalt, Braunschweig, West Germany).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 393-400; Discussion, p. 400. 5 refs.

Report on the development of two new types of separating and focusing electrodes for use in beam masers. Their performance is related to that of electrodes developed for use in an ammonia beam maser with a flat bandlike beam and a rectangular resonator. Six different focusers of the new type are investigated and compared with a four-pole and a six-pole electrode. The properties of the focusers are listed. It is seen that maser oscillation can be achieved with focusers of very small dimensions - e.g., length 1.1 cm, inner diameter 0.1 cm.

A64-23402

APPLICATION OF THE AMMONIA MASER AMPLIFIER TO E.S.R. SPECTROSCOPY.

W. A. Gambling and T. H. Wilmshurst (Southampton, University, Dept. of Electronics, Southampton, England).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 401-407.

Research supported by the Ministry of Aviation.

Description of an arrangement whereby the sensitivity of an electron spin resonance spectrometer is improved by the addition of a low-noise maser amplifier. The methods for stabilizing the frequency and gain are described. Superheterodyne detection is used to ensure a low noise factor before introduction of the maser, which is connected between the spectrometer bridge and the microwave mixer. Double modulation of the magnetic field at 465 kc is employed to allow a long recording time and thus further reduce the noise. Advantages are the lack of requirement for liquid helium and for an HF pumping source. Disadvantages are the small gain-bandwidth product of 7 kc and the low power saturation level of 10 watts. Preliminary results in the amplification of electron spin resonance signals are given.

A64-23404

BIHARMONIC OSCILLATION OF MOLECULAR BEAM AMMONIA MASER.

A. I. Barchukov, A. M. Prokhorov, and V. V. Savransky (Academie des Sciences, Moscow, USSR).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3rd, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 419, 420.

Investigation of beating between modes observed during the operation of an ammonia maser at the line $J = 3, K = 3$, with $\lambda = 1.25$ cm. Under ordinary conditions the frequency of the beats is about 3.8 kc. The phenomenon is explained in terms of inhomogeneous broadening of the transition line, possibly as a result of Stark level splitting and the Doppler effect.

A64-23405

RADIO-ELECTRONIC APPLICATIONS OF THE AMMONIA MASER [APPLICATIONS RADIOELECTRIQUES DU MASER A AMMONIAC].

J. Hardin, M. Olivier and R. Ravaut (Centre National de la Recherche Scientifique, Laboratoire de l'Horloge Atomique, Besançon, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 421-424. In French.

Description of an X-band oscillator of moderate power and high spectral purity built by phase-locking a klystron to an ammonia maser. It is claimed that the process may be readily generalized to other frequencies by means of harmonic detection. Applications to metrology and spectroscopy are discussed. The use of the maser in electron spin resonance is evaluated.

A64-23407

ATOMIC HYDROGEN MASER [MASER A HYDROGENE ATOMIQUE].

C. Menoud, J. Racine, and P. Kartaschoff (Laboratoire Suisse de Recherches Horlogères, Neuchâtel, Switzerland).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 433-438. 7 refs. In French.

Construction of a maser based on a principle first demonstrated by Ramsey, Goldenberg, and Kleppner in 1960. A stability of 10^{-13} has already been attained, and an accuracy of 10^{-11} to 10^{-12} is seen to be realizable.

A64-23408

RELAXATION MECHANISMS, DISSOCIATIVE EXCITATION TRANSFER AND MODE PULLING EFFECTS IN GAS LASERS.

W. R. Bennett, Jr. (Yale University, Sloane Physics Laboratory, New Haven, Conn.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Federation Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 441-457, Discussion, p. 457, 458. 23 refs.

USAF-supported research.

Review of background material and contributions to the theory of gas laser operation. The results of radiative lifetime studies are given. Following up an accidental discovery by Patel, data are obtained illustrating the complex exponential decay of the 7^3D

term of helium caused by reciprocal collision transfer effects. To overcome a basic difficulty with the two-body collision process used in the helium-neon laser (the fact that the energy coincidence between the initial and metastable level and the final excited maser level must be of the order of a few kT for the process to be at all probable), a more general method is proposed in which a metastable atom is used to dissociate a molecule, leaving one constituent atom in the upper maser level. An example given is the neon-oxygen laser at 8441 Å. Energy levels pertinent to the neon-oxygen and the argon-oxygen lasers and the total velocity-averaged destructive cross sections for Ne-O₂, Ar-O₂, and Kr-O₂ collisions are reproduced. It is noted that hole-burning effects can result in an anomalous increase of beat frequencies between adjacent modes with increasing pumping power in the helium-neon laser. An approximate alternative to Lamb's approach to the multimode gas laser problem is given. A pushing or hole-repulsion effect is derived that is seen to be a fairly linear function of the frequency separation from the line center when the maser is tuned near this center.

A64-23409

SELECTIVE EXCITATION BY PHOTODISSOCIATION OF MOLECULES.

G. Gould (TRG, Inc., Syosset, N. Y.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 459-467. 5 refs.

ARPA-sponsored research; Contract No. AF 49(638)-673.

Examination into the reasons for the disappointing gain, power/volume ratio, and efficiency of CW gas laser oscillators. Internal discharge (He-Ne, He-Xe, Ar-O₂) and optically pumped (He-Cs) media are compared. The gain equation is expressed as a product of five factors. It is seen that the shorter the wavelength, the faster one must pump to maintain a population inversion and that the narrower the fluorescent line, the higher the gain. A laser pumped by photodissociation of thallium bromide gas by mercury resonance radiation is proposed to obviate or circumvent the difficulties. It is estimated that for a wavelength of 5350 Å, at a pressure of 1-mm Hg in a 1-cm tube, a gain of 0.0010/cm, power/volume of 10.0 mw/cm³, and overall efficiency of 1% are attainable.

A64-23411

OPTICAL HETERODYNING WITH A CW GASEOUS LASER.

S. F. Jacobs and P. J. Rabinowitz (TRG, Inc., Syosset, N. Y.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 481-487.

USAF-supported research.

Experimental results in optical heterodyne detection with a laser local oscillator beam made spatially and temporally coherent with an incoming signal. It is shown that: (1) the SNR is preserved provided that the local oscillator photocurrent is greater than the background (or dark) average current; and (2) under the above conditions, the signal-to-noise power ratio corresponds, within experimental error, to the theoretical value $S/N = \eta N/\Delta f$, where η is the detection quantum efficiency, N is the signal beam photon arrival rate, and Δf is the detection frequency bandpass.

A64-23414

HIGH GAIN MEDIUM FOR GASEOUS OPTICAL MASERS.

C. K. N. Patel, W. L. Faust, and R. A. McFarlane (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 507-514; Discussion, p. 513. 9 refs.

Report of a gaseous medium capable of large optical amplifications at a wavelength of 2.026 μ. The medium contains a mixture of He and Xe. It has yielded optical gain as high as 4.5 db/m at 2.026 μ corresponding to the 5d [3/2]⁰ - 6p [3/2]₁ transition of Xe (Racah notation). A large increase is found in the optical gain on addition of relatively large amounts of He to Xe. The excitation processes leading to the high optical gain are described. The mechanism involves electron impact alone. The reported gains are measured by a direct and an indirect method, yielding slightly different results which are discussed. It is found that the optical gain as measured in a cylindrical discharge tube varies inversely as the diameter of the tube. This observation is in qualitative agreement with a similar observation in the case of He-Ne reported by Bennett.

A64-23415

USE OF A GAS LASER TO STUDY THE AMPLIFICATION OF A GAS MIXTURE [UTILISATION D'UN LASER A GAZ POUR L'ETUDE DE L'AMPLIFICATION D'UN MELANGE GAZEUX].

R. Grudzinski and J. Spalter (Compagnie Générale d'Electricité, Paris, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 515-521; Discussion, p. 521. 11 refs. In French.

Experimental and theoretical analysis of the parameters influencing the amplification of an He-Ne gas mixture. The parameters include the tube diameter, the gas pressure, and the conditions of excitation. Homogeneity and reproducibility are obtained by the use of a continuous current discharge. The effect of helium on the amplification is seen to be due to its action on the electron distribution, whereby excitation of the s level is favored without impedance of the blocking effect on the p level. Additions of argon and mercury are found to have a negative effect in that both elements impoverish the distribution of high-energy electrons.

A64-23416

ZEEMAN EFFECTS IN HELIUM-NEON LASERS.

W. Culshaw and J. Kannelaud (General Telephone and Electronics Laboratories, Inc., Palo Alto, Calif.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.

New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 523-535. 15 refs.

Experimental investigation of the effects of small stray and applied magnetic fields on the polarization and frequency content of the He-Ne planar laser output. For isotropic reflectors, the polarizations are found to be governed by the orientation of the

magnetic field. In general, for transverse and axial fields, these will be linear, or circular, and orthogonal at high fields. At lower fields, elliptical polarization due to coherence effects may be observed. For a horizontally transverse field, departures from the usual horizontal and vertical polarizations have been observed, and there is also apparently a preferred orientation of the linear polarization for zero solenoid current. Such effects are considered to be due to anisotropy in the reflecting films leading to a preferred direction of polarization in the laser buildup.

A64-23422

PROPERTIES OF MATERIALS FOR SUBMILLIMETER MASERS. W. S. C. Chang (Ohio State University, Dept. of Electrical Engineering, Antenna Laboratory, Columbus, Ohio) and R. F. Rowntree (Ohio State University, Dept. of Physics, Laboratory of Molecular Spectroscopy and Infrared Studies, Columbus, Ohio). IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen. New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 677-684. 11 refs. Grant No. NsG-74-60.

Consideration of the particular conditions that are necessary to successfully operate a solid-state submillimeter maser and the measured properties of the host lattice and the cavities that could be used for such a development. Expressions representing the conditions for oscillation are presented relating the cavity Q, the wavelength, the linewidth of the transition, and the statistical weights and population densities of the signal and terminal states. It is found that the successful development of a submillimeter maser must depend upon the selection of an active material that would have a $Q_{abs} = 10^3$ or better, with a population inversion of 10% or better. This is interpreted to mean that any material within which an electric dipole transition does not occur will probably not make a good submillimeter maser material.

A64-23427

LOW LYING ENERGY LEVELS AND COMPARISON OF LASER ACTION OF U^{3+} in CaF_2 .

S. P. S. Porto and A. Yariv (Bell Telephone Laboratories, Inc., Murray Hill, N. J.). IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen. New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 717-723. 11 refs.

Electron paramagnetic resonance investigation of laser action in the calcium fluoride-uranium system. The crystals were found to contain U^{3+} ions in sites of fourfold symmetry (tetragonal sites) in which the excess positive charge is compensated by an F^- ion in the nearest interstice. These are the U^{3+} sites first described by Bleaney. Also noted are previously unobserved sites of U^{4+} with trigonal symmetry in which charge compensation is obtained via the replacement of the two nearest F^- ions along the $\langle 111 \rangle$ direction by two O^{2-} ions, and sites of U^{3+} in orthorhombic sites which are due to charge compensation by an F^- ion in the next nearest (or second nearest) interstice. The relative amounts of each of the three uranium species in each crystal are determined, and fluorescence and emission data are obtained. By correlating the intensity variations with the electron paramagnetic resonance analysis, it is found possible to isolate the spectra of the three types of uranium ions, and from these to construct the low-lying energy levels and determine which sites are responsible for the various laser frequencies.

A64-23429

MATERIALS TRANSPARENT IN THE FAR-INFRARED (50-1600 μ) - APPLICATION TO OPTICAL MASERS [MATERIAUX TRANSPARENTS DANS L'INFRAROUGE LOINTAIN (50 - 1600 MICRONS) - APPLICATION AUX MASERS OPTIQUES].

A. Hadni, B. Wyncke, P. Strimer, E. DeCamps, and J. Claudel (Nancy, Université, Faculté des Sciences, Nancy, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen. New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 731-740. 11 refs.

Studies of the electron transitions between ground-state Stark levels of alkaline earth and alkali metal halides doped with rare-earth ions. The halides investigated include CaF_2 , SrF_2 , LaF_3 , and CsI . Doping is with $Nd(NO_3)_3 \cdot 6H_2O$, $Sa(NO_3)_3 \cdot 6H_2O$, and $TmCl_3$. At the temperature of liquid helium, the low-frequency wing of the main absorption band tends to disappear. This result is attributed to transitions of the wave vector from an acoustic to an optical mode.

A64-23430

STEADY STATE POPULATION DISTRIBUTIONS IN QUANTUM MECHANICAL SYSTEMS.

W. A. Barker and J. D. Keating (McDonnell Aircraft Corp., St. Louis, Mo.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen. New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 741-749. 12 refs.

General solution for the population distribution in three- and four-level systems. The solution is applied to the three-level microwave maser, the three- and four-level optical maser, and the four-level push-push and push-pull microwave maser. The results include expressions for the inversion condition, signal power output, and pump power absorbed for the microwave and optical masers. The nuclear polarization is calculated for the Overhauser effect.

A64-23435

INVESTIGATIONS OF A EUROPIUM CHELATE SOLUTION AS A POTENTIAL LIQUID OPTICAL MASER.

R. C. Ohlmann, E. P. Riedel, R. G. Charles, and J. M. Feldman (Westinghouse Electric Corp., Research Laboratories, Pittsburgh, Pa.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen. New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 779-784. Discussion, p. 785. 5 refs.

Spectroscopic study of solutions of europium trisdibenzylmethide ($Eu[DBM]_3$) in dimethylformamide, di-n-propylamine, and ethanol. The excitation, absorption and emission spectra, the quantum efficiency, and the fluorescent decay time of the principal emission line are measured as functions of temperature and solvent. A calculation based on the results indicates that optical maser action may be achieved with this material.

A64-23438

THE $\text{CaF}_2 : \text{Tm}^{2+}$ AND THE $\text{CaF}_2 : \text{Dy}^{2+}$ OPTICAL MASER SYSTEMS.

Z. J. Kiss (Radio Corporation of America, RCA Laboratories, Princeton, N. J.).
IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.
New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 805-815. 8 refs.

Use of divalent rare earths to overcome one of the most important practical limitations of optically pumped solid-state laser materials: the lack of suitable absorption bands of the active ions in convenient spectral regions. The maser transitions of the $\text{CaF}_2 : \text{Tm}^{2+}$ and $\text{CaF}_2 : \text{Dy}^{2+}$ systems are identified, and energy levels including the crystal field symmetries of the states are presented. Recent studies of the magnetic behavior of the systems are described and continuous operation of the $\text{CaF}_2 : \text{Tm}^{2+}$ maser is reported.

A64-23440

LARGE ZINC TUNGSTATE CRYSTALS FOR MICROWAVE MASER APPLICATIONS.

J. J. Rubin, W. G. Nilsen, and L. G. Van Uitert (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.
New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 825-831. 6 refs.

Fabrication by the Czochralski technique of large $\text{ZnWO}_4 : \text{Cr}$ crystals suitable for comb structure masers. The inversion of Cr^{3+} in zinc tungstate is found to be effected at three times the volume concentration in Al_2O_3 . Preliminary measurements indicate that the gain and power of a $\text{ZnWO}_4 : \text{Cr}$ comb structure maser operating at 1.4 Gc should be significantly greater than that of a corresponding pink ruby maser. The problems involved in removing the zinc tungstate crystals from the melt are discussed.

A64-23441

SUBSTITUTION AND CHARGE COMPENSATION IN CALCIUM TUNGSTATE OPTICAL MASER CRYSTALS.

K. Nassau (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.
New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 833-839. 12 refs.

Investigation of the effect of alkali metal ions on the distribution coefficient of Nd^{3+} in CaWO_4 . This combination provides the only solid-state optical maser material that can give continuous operation at room temperature. Preliminary experiments indicate that the distribution coefficient (k_{Nd}) at a fixed melt sodium concentration varies with the melt neodymium concentration. Accordingly, it is seen that a full representation of any such system requires the construction of two three-dimensional surfaces, representing the dependence of the distribution coefficients of the rare-earth and of the alkali metal on the melt concentration of both species. For optimum maser operation, complete charge compensation is found desirable in order to eliminate unwanted spectra. This indicates

the need for a large excess of alkali-metal ions in the melt. Melt concentrations for the growth of crystals that will operate continuously at room temperature are found to be approximately 15 atomic % sodium and 4 atomic % neodymium.

A64-23446

INVESTIGATION AND REALIZATION OF AN S-BAND MASER [ETUDE ET REALISATION D'UN MASER BANDE S].

M. Bidault (Compagnie Française Thomson-Houston, Service d'Etudes Techniques Avancées, Paris, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.
New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 883-898. In French.

In French.

Description of a three-level solid-state maser operating in the S-band. Its pump frequency is in the Ku band (13,700 Mc) and its active material is a ruby crystal. From an investigation of the spin Hamiltonian, the energy levels and corresponding eigenstates of the chromium ion, the probabilities of induced transitions between levels are calculated. From these data it is then found possible to determine the magnetic field H_0 (~ 2750 gauss), the 90° orientation of the crystal optic axis to the H_0 direction, the optimum polarization of the signal, and the pump microwave fields. The shape of the selected Hamiltonian is verified by an experimental study of the pump and signal absorption lines. The spin-spin relaxation is found through an analysis of the resonance curves. Saturation experiments provide measurements of the spin-lattice relaxation time and the real component of the paramagnetic susceptibility. The amplification process and gain, bandwidth, and noise temperature are examined.

A64-23451

OSCILLATION CHARACTERISTICS AND ITS TEMPERATURE DEPENDENCE OF A PULSED RUBY MASER.

F. Saito (Nippon Electric Co., Fundamental Research Laboratory, Kawasaki, Japan).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.
New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 937-941. 5 refs.

Quantitative investigation of the dynamic characteristics of an X-band pulsed ruby maser. A semi-empirical expression is presented relating the time duration t_d that the oscillation pulse lags behind the pumping pulse to the peak level P of the pumping power, the period T , and the width τ of the pumping pulse. In the expression certain parameters appear that depend on temperature and other operating conditions. The precise temperature dependence from 1.6 to 20°K is studied in an effort to relate these parameters to the spin lattice relaxation time. The preliminary results are given.

A64-23455

GENERATION OF MILLIMETER WAVES IN OPTICALLY PUMPED RUBY.

G. M. Zverev, A. M. Prokhorov, and A. K. Shevchenko (Moscow State University, Institute of Nuclear Physics, Moscow, USSR).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE INTERNATIONAL CONGRESS, 3RD, PARIS, FRANCE, FEB. 11-15, 1963. VOLUME 1.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by P. Grivet and N. Bloembergen.
New York, Columbia University Press; Paris, Dunod Editeur, 1964, p. 963-966.

Experiments on the generation of mm waves in the range 35-50 Gc using a ruby maser cooled by liquid nitrogen. A ruby laser operating also at the temperature $T = 77^{\circ}\text{K}$ was used as the pumping source. The C-axis of the ruby maser crystal was oriented perpendicular to the direction of the external magnetic field. A block schematic of the experimental device is shown along with the appropriate energy level diagram for Cr^{3+} ions in ruby. The obtained mm wave pulses are reproduced.

A64-23456

QUARTZ OPTICAL PHONON-MASERS.

C. H. Becker (Precision Instrument Co., Palo Alto, Calif.),
(Institute of Radio Engineers, Ultrasonics Symposium, New York, N.Y., Nov. 28-30, 1962.)

IEEE Transactions on Sonics and Ultrasonics, vol. SU-11, June 1964, p. 34-40, 7 refs.

Experimental investigation of the possibility of stimulating emission of optical phonons in the Teracycle frequency range of 10^{12} cps in alpha-quartz by means of strong UV pumping. This phenomenon is stated to result from the quantum-mechanical excitation of the vibrational molecular modes of the alpha-quartz unit cell during second-order inelastic light-scattering processes. During the excitation period, optical phonon maser action takes place in the alpha-quartz, causing inversion of the intensities of the quartz Raman spectrum when the critical intensity of optical pumping is achieved. Optical phonons in alpha-quartz can be detected by measuring the intensity distribution of the anti-Stokes and Stokes lines during the inversion processes. It is noted that the quantum electronics of optical phonons may conceivably be established on the basis of this new phenomenon and that a radically new approach to molecular energy transport is expected.

A64-23483ON THE EMISSION SPECTRUM OF A $\text{CaF}_2:\text{Sm}^{2+}$ LASER.

Iu. A. Ananov, N. M. Galaktionova, A. A. Mak, and B. M. Sedov.
(Optika i Spektroskopiia, vol. 16, May 1964, p. 911-914.)

Optics and Spectroscopy, vol. 16, May 1964, p. 495, 496. Translation.

Experimental investigation of the emission spectrum of a laser using fluorite, activated by divalent samarium, and generating 0.708- μ radiation. The results obtained are stated to show that independent generation along different directions evidently occurs only at the initial instants of time. It is also noted that, at the initial instants, a splitting of the spectral modes into two components occurs. The magnitude of the splitting amounts to about 0.035 \AA . The reason for this splitting is said to be unclear at present.

A64-23792

CONTINUOUS PHOTOELECTRIC RECORDING OF THE RAMAN EFFECT IN LIQUIDS EXCITED BY THE He-Ne RED LASER.

R. C. C. Leite and S. P. S. Porto (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

(Optical Society of America, Meeting, Chicago, Ill., Oct. 24, 1963.)
Optical Society of America, Journal, vol. 54, Aug. 1964, p. 981-984.

Brief description of the continuous photoelastic recording of laser-excited Raman spectra obtained for nonlossy liquids. The Raman cell was placed inside the cavity of a He-Ne 6328- \AA gas laser. The power density of the exciting radiation was of the order of 100 watt/cm^2 through the sample. An SNR of more than 3000 was obtained for the 992-cm line of benzene. The laser used was of the external mirrors-Brewster angle window type, and consists of a 5:1 mixture He-Ne tube and the high-reflectance dielectric-coated mirrors. Further improvements in the recordings are suggested.

A64-23961

REVIEW OF SOLID STATE LASERS.

C. G. B. Garret (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.
Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 971-983; Discussion, p. 983, 984. 33 refs.

Discussion of the developments in the field of optically excited solid-state lasers since its beginnings in 1960. The physical principles and the orders of magnitude involved are covered. The materials used so far in optical maser experiments, the luminescent centers involved, and the various host lattices are considered. The output characteristics of solid-state lasers are then studied.

A64-23963

NEODYMIUM GLASS LASER.

E. Snitzer (American Optical Co., Southbridge, Mass.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.
Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 999-1019. 8 refs.

Contract No. DA-19-020-ORD-5575.

Discussion of the spectroscopic properties of neodymium glass, which is used in high energy output lasers and in fiber lasers. Recent results are presented on high energy configurations, effects of pump power, emission power as a function of time, the effect of the glass containing the neodymium, and on the spectrum of the light emitted. Finally, fiber lasers are considered.

A64-23964CHARACTERISTICS OF THE $\text{CaWO}_4:\text{Nd}^{3+}$ OPTICAL MASER.

L. F. Johnson (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.
Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1021-1035; Discussion, p. 1035. 11 refs.

Discussion of the spectroscopic properties and optical maser effects of neodymium in CaWO_4 . The gross features of the energy levels of Nd^{3+} in CaWO_4 , derived from absorption and fluorescence data, are presented. Emission lines displaying maser oscillation are designated, and relevant data are tabulated. A dominant line is shown to be at 1.065 μ , and the system producing this line is the subject for the remainder of the study. The effects of crystal imperfection on optical maser behavior are considered. Data gained in continuous operation experiments with the $\text{CaWO}_4:\text{Nd}^{3+}$ system are given; and such aspects of the system are discussed as spectral distribution of the maser emission, the extent to which refractive index variations due to internal strain contribute to the 10-kc width, and the phenomenon of "spiking."

A64-23965

MEASUREMENT OF FACTORS AFFECTING THRESHOLD OF A CONTINUOUSLY OPERATING RUBY OPTICAL MASER.

D. F. Nelson and D. E. McCumber (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1037-1043. 7 refs.

Presentation of experimental results on a ruby optical maser operated continuously to determine the threshold population of the metastable levels by a study of the nonlinearity of the fluorescence vs the optical pumping power. The experiments used a ruby sapphire "trumpet" which had its optical axis perpendicular to the trumpet axis. It was cut from a Linde "V-R grown" ruby-sapphire boule. Its Cr^{3+} concentration was measured by a calibrated optical absorption technique to be $2.0 \times 10^{18} \text{Cr}^{3+} \text{cm}^{-3}$. The lamp used was a Hanovia 958B lamp. Pumping of the maser crystal was changed in these experiments by varying the lamp current. The R_1 -line side fluorescence was measured as a function of particular, narrow wavelength bands of the incident pump light. Measured side fluorescence vs two of these wavelength intervals of incident pump light is presented and compared with data expected from theory. A similar study was made of the R_1 -line fluorescence out of the end of the rod at 12° off axis, and the results are also presented and compared with the results from a theoretical model. By turning off the pumping light with a high-speed chopper when the crystal was pumped just to the maser threshold, the decay of the metastable level populations as given by R_1 -line side fluorescence was measured and the results are presented. Determinations of the cross sections for absorption from the metastable levels upward were made indirectly by measuring the dependence of the pumping light at a particular wavelength emerging from the larger end of the maser crystal vs that entering it. All these results are presented in the form of plots together with plots of theoretical results. Considerable disagreement is found. It is concluded that there are two possible explanations for this disagreement. One is that the model is inadequate in its formulation to handle properly totally entrapped rays. A second is the possibility that the absorption from the metastable levels is a two-ion process.

A64-23969

STIMULATED OPTICAL EMISSION FROM RUBY AT LIQUID NITROGEN TEMPERATURE.

V. K. Konjukhov, L. A. Kulevsky, and A. M. Prokhorov (Academy of Sciences, Physics Institute, Moscow, USSR).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1067-1070.

Discussion of an experiment conducted to investigate the spectral component characteristics of the emission from a ruby laser at $T = 77.4^\circ$. A pink ruby laser rod of 6-mm diam. and a length of 60 mm was chosen for the experiment. The stimulated spectrum is found to have two components. At threshold pumping, the laser beam is seen to have only a shortwave component corresponding to the transition to the sublevel $\pm 3/2$. With increasing pumping there appears the second, longwave component. The splitting of the components is found to be $(0.36 \pm 0.03) \text{cm}^{-1}$. This splitting coincides with errors with crystal-field splitting of the 4A_2 ground level of Cr^{3+} ion in the Al_2O_3 lattice. The variation of the components intensity with time is presented for the pumping level near threshold and for the pumping level twice threshold.

A64-23974

DYNAMIC LIMITATIONS ON THE ATTAINABLE INVERSION IN RUBY LASERS.

W. R. Sooy, R. S. Congleton, B. E. Dobratz, and W. K. NG (Hughes Aircraft Co., Aerospace Group, Culver City, Calif.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1103-1112.

Discussion of the effects of spontaneous decay, superradiance, prelasering, lateral depumping, and internal modes. Of these depumping mechanisms possible in a ruby laser, only internal modes appear to be a substantial problem with state-of-the-art lasers, which are typically small, low-gain, and inefficiently used. However, theoretically, all of the described mechanisms are seen as limiting in larger, more efficient devices and they must be accommodated in laser design. A combination of immersion, selective filtering, and end wall canting is suggested for the elimination of internal modes, prelasering, and lateral depumping. Spontaneous decay and superradiance, however, are intrinsic limitations.

A64-23975

BEATS AND MODULATION IN OPTICAL RUBY-MASERS.

K. Gürs (Siemens und Halske AG, Forschungslaboratorium, Munich, West Germany).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1113-1119. 6 refs.

Presentation of the experimental results obtained with a system in which the plane-parallel ruby crystal is fully silvered on one side. The optical maser oscillates between this and a concave mirror at a distance of 2 to 20 m. In addition, a convergent lens is arranged within the resonator near the ruby. For different positions of the lens, the resonator represents a confocal or a concentric system. By moving the lens along the axis of the resonator, setups are obtained which favor the existence of a few or one to several modes. Oscillograms are presented for resonator lengths of 2, 10, and 20 m. It is shown that, given a proper choice of the focal length of the mirror and the lens, the continuous component will prevail over the oscillations practically from the beginning of the emission. In agreement with theory, the period T increases proportionally to the square root of the resonator length L . Cooling of the crystal will reduce the period of oscillation and the damping constant τ_0 according to the change of lifetime τ and linewidth $\Delta\nu$. An arrangement for internal modulation by KDP is presented, and experimental results are given. Internal modulation is limited in its bandwidth. However, only minor changes in the resonator are required for full modulation. Therefore, only a small fraction of the voltage required for external modulation is necessary. This kind of modulation is shown at 1 Mc/sec for an arrangement with a mirror spacing of 20 cm.

A64-23976

DYNAMIC BEHAVIOR OF QUANTUM MECHANICAL OSCILLATORS.

G. Makhov and O. Risgin (Michigan, University, Institute of Science and Technology, Ann Arbor, Mich.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1121-1129. 12 refs.

Analysis of the rate equations of the three-level maser to determine the conditions for the existence - in terms of material and circuit parameters - of the following three modes of operation: (1) an overdamped, (2) an oscillatory transient decaying to an unmodulated steady-state output, and (3) recurrent sharp pulses at nearly equal amplitude. Semiquantitative methods and nonlinear mechanics are used in the analysis. The analysis shows that the elementary rate equations provide adequate description of the two CW modes, but do not admit periodic solutions, and thus cannot account for the recurrent pulses. In order to include the pulsed modes of operation in the description, the population difference equation is augmented by an arbitrary function of population difference and of energy in the resonator, with the circuit equation remaining unaltered. A reference to experimental data shows that the processes producing recurrent pulses are not alike in the microwave and optical cases. The processes involved are considered.

A64-23977**TEMPERATURE AND CONCENTRATION EFFECTS IN A RUBY LASER.**

I. J. D'Haenens and V. Evtuhov (Hughes Aircraft Co., Research Laboratories, Malibu, Calif.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1131-1139. 5 refs.

Investigation to determine the threshold dependence of Cr^{3+} ion concentration on: the ruby diameter and length, the reflectivity of the cavity end plates, and the operating temperature, for short pulse operation of a ruby laser. The results of the analysis are extended to apply to cases of arbitrary pulse duration. Experimental results are presented and compared with the analysis. Good agreement is obtained.

A64-23979**SOLID STATE X-RAY MASERS.**

L. Gold (Ledgemont Laboratory, Lexington, Mass.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1155-1160.

Discussion of considerations in extending the maser frequency of operation into the X-ray region. Properties of the pump source are considered, and the performance of the secondary source is covered. The distinction between X-ray and optical levels in atoms is noted in terms of the electronic configurations. The X-ray response of impurity atoms in a host crystal is then discussed. It is pointed out that the radiation emitted from the distributed atoms will inherently be incoherent. Even if the individual sources are not randomly distributed in the parent crystal, coherency will not automatically occur. This problem is studied allowing for the diffractive properties of the X-ray quanta.

A64-23981**MODES IN CONFOCAL GEOMETRIES.**

G. D. Boyd (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1173-1186; Discussion, p. 1186. 22 refs.

Review of the work of many scientists whose efforts contribute to the theory of multimode resonators and periodic transmission systems at optical and mm wavelengths. Among others, consideration is given to Schawlow and Townes' classical paper on "Infrared and Optical Masers," Prokhorov's "Molecular Amplification and Generation for Submillimeter Waves," and Fox and Li's work on "Resonant Modes in an Optical Maser" and "Resonant Modes in a Maser Interferometer." Ideas presented in Goubau and Schwering's "On the Guided Propagation of Electromagnetic Wave Beams" are also summarized. It is emphasized that, first, a resonator formed by two curved reflectors separated by almost any distance up to twice their curvature will work satisfactorily as a high Q optical resonator. Second, the absence of the side walls is necessary to an optical maser resonator to limit the number of modes with high Q. Finally, using the Fox and Li concept of a self-consistent field to define a mode and recognizing the large number of equivalent possibilities shown in the discussion of a periodic sequence of lenses, a large number of useful combinations is expected in future developments. Application is seen in future devices as mode filters, harmonic generators, and couplers, in the field of optical masers.

A64-23983**STRUCTURE OF GIANT OPTICAL PULSES FROM RUBY.**

R. W. Hellwarth (Hughes Aircraft Co., Research Laboratories, Malibu, Calif.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1203-1209; Discussion, p. 1209, 1210. 17 refs.

Discussion of the observed properties of the giant laser pulses, aimed at pointing out the various physical processes in the ruby and the optical cavity. The fast switching type of Q-switching is discussed and illustrated. Experimental results, obtained so far, are included; certain features of giant pulses which have become fairly evident are considered; and explanations are suggested.

A64-23984**HIGH GAIN, HIGH POWER PULSED RUBY OPTICAL AMPLIFIER.**

J. E. Geusic and H. E. D. Scovil (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1211-1220; Discussion, p. 1220. 6 refs.

Contract No. DA-36-039-SC-89068.

Review of earlier work on the unidirectional traveling wave optical maser (TWOM) amplifier, including a discussion of recent experiments with a high gain pulsed ruby TWOM which were not reported on before. The TWOM's unconditional stability and its greater bandwidth - as compared to a regenerative amplifier of comparable gain - are pointed out. The TWOM amplifier is described and its characteristics and capabilities are discussed. Experiments with a high gain TWOM are then considered, and its high gain and high power capabilities demonstrated.

A64-23988

STUDY OF MODES OF OSCILLATION IN LASERS WITH SPHERICAL TERMINAL MIRRORS [ETUDE DES MODES D'OSCILLATIONS DES LASERS A MIROIRS TERMINAUX SPHERIQUES].

M. Pauthier (Laboratoire Central des Télécommunications, Paris, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen. Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1253-1262; Discussion, p. 1262. In French.

Presentation of a simple method using only elementary principles of geometrical optics to calculate the configuration of the electromagnetic field which can be observed in a gas laser with spherical mirrors. The presented method yields the same results concerning positioning of the mirrors for closed light-beam configurations as the method used by Boyd and Gordon and Boyd and Kögelnik, which takes a completely different approach and which is more involved. The experimental verification of certain striking points gives satisfactory results.

A64-23989

MODES IN A MASER INTERFEROMETER WITH CURVED MIRRORS.

A. G. Fox and Tingye Li (Bell Telephone Laboratories, Inc., Holmdel, N. J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen. Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1263-1270, 7 refs.

Investigation of the two-dimensional problem of infinite-strip mirrors. The results, however, are applicable to the three-dimensional problem of rectangular mirrors. The integral equations defining the modes of the interferometer were derived using Huygens' principle to compute the field distribution of a wave which is reflected to and fro between the two mirrors. The geometry of an infinite-strip curved-mirror interferometer and the integral equations that relate the field distribution over one mirror to that over the other are shown. The loss of each mode for a given Fresnel number is studied, and a contour diagram is presented of the computed loss function for the dominant mode of a pair of curved infinite-strip mirrors of the same width. This diagram is computed for a single value of the Fresnel number. The loss of the dominant mode was computed also for other values of the Fresnel number. It was found that it decreases monotonically with the Fresnel number for configurations corresponding to points lying in the low-loss regions but that it fluctuates without eventual decrease in the high-loss regions. This is illustrated for a family of pairs of identical mirrors. The relative amplitude and phase distributions of the field intensity of the dominant mode of a family of infinite-strip curved-mirror interferometers with identical mirrors for Fresnel number = 1.0 are presented and discussed. The diffraction losses for the two lowest-order modes of an infinite-strip concentric interferometer with a midplane aperture are considered as functions of the normalized aperture width. The mode selective property of the aperture concentric interferometer is studied.

A64-23992

ISOLATION OF AXI-SYMMETRICAL OPTICAL-RESONATOR MODES.

W. W. Rigrod (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen. Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1285-1290, 8 refs.

Discussion of the isolation of 15 axisymmetric modes of the concave-mirror interferometer, forming the external cavity of a helium-neon maser tube with Brewster-angle windows. The experimental technique is described, and the results are discussed. The isolation mechanism is suggested to depend on physical processes in the maser medium, rather than on purely optical phenomena.

A64-23993

INTERFEROMETER LASER MODE SELECTOR.

S. A. Collins and G. R. White (Sperry Rand Corp., Sperry Gyroscope Co., Great Neck, N. Y.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen. Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1291-1300, 5 refs.

Study of the operation of a laser with a new mode selector formed from a Fabry-Perot etalon placed internal to the laser and tipped with respect to the laser axis cavity. Frequency rejection due to the mode selector's frequency transmission characteristics is demonstrated along with a decrease in beam angle, caused by tilting the mode selector etalon. An increase in peak photometric intensity is also shown.

A64-23997

THE S-66 LASER SATELLITE TRACKING EXPERIMENT.

H. H. Plotkin (NASA, Goddard Space Flight Center, Greenbelt, Md.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen. Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1319-1332.

Discussion of the optical tracking experiment planned by NASA for the S-66 satellite, which consists of illuminating a special satellite-borne reflector with a pulse from a laser and of receiving the reflected light to measure the time-of-flight in order to determine the accurate range. The reflector is described. It is composed of a mosaic of fused quartz cube-corners, each about 1 in. across the face. The velocity aberration effect is considered to justify the use of a mosaic of small retroreflectors instead of fewer but larger ones. The satellite and the pulsed ruby laser which NASA will use during the S-66's early life are described. The signals which might be expected in a typical situation are considered. The equipment which will be used shortly after the satellite is launched is presented. The real-time automatic digital optical tracker being developed for the acquisition of the satellite within the narrow laser beam over a full 24 hours is studied.

A64-23998

PHOTO-MACHINING WITH LASER GENERATOR [USINAGE PHOTONIQUE AVEC GENERATEUR LASER].

M. S. Bruma (Paris, Université, Faculté des Sciences, Laboratoire de Chimie Physique, Paris, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

A64-24004

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1333-1337; Discussion, p. 1337. In French.

Presentation of the physical mechanism underlying the process of machining using a laser beam. Factors affecting the mechanical effects are considered.

A64-24004

THE SELASER LAMP - A UNITARY DESIGN FOR THE EMISSION OF STIMULATED RADIATION.

R. C. Vickery and J. V. Fisher (Semi-Elements Inc., Saxonburg, Pa.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolass Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1397-1403.

Presentation of designs for a Selaser lamp, in which the laser crystal is activated internally. This design obviates the use of external pumping sources such as helical or U-shaped lamps with their accompanying light energy losses. Characteristics and operating parameters are presented.

A64-24007

CALCULATION OF GIANT PULSE FORMATION IN LASERS.

B. A. Lengyel and W. G. Wagner (Hughes Aircraft Co., Research Laboratories, Malibu, Calif.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolass Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1427-1436.

Analysis of the fast switching case, characterized by a switching of the shutter or cavity Q in time so short that no significant change of population inversion takes place during the switching process. In formulating the equations which govern the process of stimulated emission in the period following the switching, the effects of processes which are slow in comparison to the formation of the giant pulse are neglected. Two nonlinear differential equations are obtained for the population inversion and the photon density. After proper normalization, the equations retain only one parameter which is descriptive of the laser. The first integral of the equations yields the total energy obtainable from the pulse, the population inversion remaining, and the peak power.

A64-24010

AN INTERNALLY REFLECTING OPTICAL RESONATOR WITH CONFOCAL PROPERTIES.

D. F. Holshouser (Illinois, University, Electrical Engineering Dept., Urbana, Ill.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolass Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1453-1458.

Presentation of the configuration of an internally reflecting surface which exhibits properties of a spherical mirror. Experimental results are included which were obtained with a semi-confo-cal optical maser using this configuration.

A64-24014

COHERENCE, SPECTRA TIME SCANNING AND PULSATIONS OF THE LASER EMISSION.

Z. A. Chizhikova, M. D. Galanin, V. V. Korobkin, A. M. Leontovitch, and V. N. Smortchkov (Academy of Sciences, USSR). IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolass Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1483-1491. 16 refs.

Study of the time dependence of the excitation of axial modes during the pulse operation of a laser. The study includes an investigation of the radiation coherence, time scanning of the laser emission performed by using a high-speed mirror-camera, and an examination of the laser emission spectra using a Fabry-Pérot interferometer during a pumping pulse with and without time scanning. The experiments are carried out at temperatures of the ruby rod from +20 to -165°C. The experimental results are discussed.

A64-24023

RAMAN LASER ACTION IN ORGANIC LIQUIDS.

E. J. Woodbury (Hughes Aircraft Co., Aerospace Group, Culver City, Calif.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolass Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1577-1588; Discussion, p. 1588. 6 refs.

Description of the work leading to the discovery of laser action in certain organic liquids, believed to be due to stimulated Raman scattering. An abbreviated form of the phenomenological theory developed by Hellwarth is presented, and experimental observations are included. The results obtained so far show the following trends: (1) only ring compounds with five or more C-H bonds have produced strong stimulated emission, (2) no such liquid compound tested has failed to produce such emission. However, the power and energy of the illuminating laser used for most of this work were well below those available now.

A64-24038

HARMONIC GENERATION AND MIXING OF CaWO_4 : Nd^{3+} AND RUBY PULSED LASER BEAMS IN PIEZOELECTRIC CRYSTALS.

R. C. Miller (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen.

Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1695-1702. 17 refs.

Discussion covering second harmonic generation with two Nd lasers: Nd-doped CaWO_4 and Nd-doped glass, mixing of the CaWO_4 : Nd^{3+} and ruby laser beams, and the determination of the matching conditions for the second harmonic generation and mixing of these laser beams in ammonium dihydrogen phosphate (ADP) and potassium dihydrogen phosphate (KDP).

A64-24039

INTERACTIONS BETWEEN TWO Nd^{3+} GLASS LASERS.

C. J. Koester, R. F. Woodcock, E. Snitzer (American Optical Co., Southbridge, Mass.), and H. M. Teager (Massachusetts Institute of Technology, Cambridge, Mass.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen. Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1703-1710. USAF-supported research.

Discussion of experiments demonstrating that quenching of laser oscillation can be accomplished using the output of another laser having the same emission wavelength. The effect is observed to be at least as fast as 1μ sec. The experimental arrangement is described and experimental results are included.

A64-24045

A NEW PRINCIPLE IN THE DESIGN OF A MILLIMETRIC PHOTO-ELECTRIC LASER MIXER.

A. L. Cullen and P. N. Robson (Sheffield, University, Sheffield, England).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen. Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1741-1750.

Analysis showing that the transverse current wave resulting from mixing two laser beams on a plane photo-emissive surface can have a wide range of phase velocities depending on the direction of the two beams with respect to the surface. Several configurations of potential interest in the design of a practical mixer are considered.

A64-24047

SEMICONDUCTOR MASERS [MASERS A SEMI-CONDUCTEURS]. P. Aigrain (Ecole Normale Supérieure, Laboratoire de Physique, Paris, France).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen. Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1761-1766; Discussion, p. 1766, 1767. 17 refs. In French.

Survey of ideas concerning semiconductor masers and lasers. Possible semiconductor maser and laser types are considered, and experimental results are discussed.

A64-24057

GaAs INJECTION LASER.

M. I. Nathan and G. Burns (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen. Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1863-1872. 25 refs.

Presentation of investigation results on the stimulated emission in GaAs p-n junctions. Most of the presented measurements were made at 77°K. The nature of the transition and the spectral character of the stimulated emission are discussed. The temperature dependence of the stimulated emission and CW operation are studied, and directionality effects are considered.

A64-24061

SEMI-CONDUCTOR LASER ON P-N JUNCTIONS IN GaAs.

V. C. Bagaev, N. G. Basov, B. M. Wul, B. D. Kopylovsky, O. N. Krokhin, Iu. M. Popov, E. P. Markin, A. N. Khvoshev, and A. P. Shotov (Academy of Sciences, Physics Institute, Moscow, USSR).

IN: QUANTUM ELECTRONICS; PROCEEDINGS OF THE THIRD INTERNATIONAL CONGRESS, PARIS, FRANCE, FEBRUARY 11-15, 1963. VOLUME 2.

Conference sponsored by the Union Radio Scientifique Internationale /URSI/, Fédération Nationale des Industries Electroniques, and Office of Naval Research.

Edited by Pierre Grivet and Nicolaas Bloembergen. Paris, France, Dunod Editeur; New York, Columbia University Press, 1964, p. 1891-1897. 9 refs.

Analysis yielding a definition of the conditions of laser self-excitation. It is shown that the spectral width of the radiation line diminishes at the approach to the self-excitation threshold. An expression is also presented for the efficiency of the semiconductor laser. Experimental observations on the narrowing of the radiation line are included. Oscillation of the coherent radiation in GaAs p-n junctions cooled to 77°K is investigated. The region of luminescence of the crystal is observed with an infrared microscope.

A64-24073

AN IMPROVED METHOD OF MECHANICAL Q-SWITCHING USING TOTAL INTERNAL REFLECTION.

R. Daly and S. D. Sims (TRG, Inc., Melville, N. Y.). Applied Optics, vol. 3, Sept. 1964, p. 1063-1066. 6 refs. Army-supported research.

Qualitative discussion of the kinetics of a Q-switched laser. It is shown that the occurrence of multiple pulses can be prevented by the use of a sufficiently fast switch. A Lummer-Gehrcke plate used in a novel fashion in conjunction with a rotating prism is shown to be a "fast" switch. Experimental results are presented which show substantial improvement over previous Q-switching schemes.

A64-24074

CHOICE OF MIRROR CURVATURES FOR GAS LASER CAVITIES.

Douglas C. Sinclair (Rochester, University, Institute of Optics, Rochester, N. Y.). (Optical Society of America, Fall Meeting, Washington, D. C., 1963.)

Applied Optics, vol. 3, Sept. 1964, p. 1067-1071. Army-supported research.

Brief review of transverse mode structure in various curved mirror laser cavities. Cavities considered are those consisting of two concave mirrors, a concave and a plane mirror, and a concave and a complex mirror. The volume of the TEM₀₀ mode in the various cavities is discussed, and the alignment tolerance on the mirrors is considered. It is shown that the maximum volume of TEM₀₀ mode in the near-hemispherical cavity is roughly 1/3 of the volume in the plane parallel cavity, but that for a given mode volume, the near hemispherical cavity is the easiest of all curved mirror cavities to align. It is suggested on the basis of the above consideration that the near-hemispherical cavity is the most practical cavity to use in a laser.

A64-24198

LARGE-AMPLITUDE SOLUTIONS OF THE RATE EQUATIONS FOR THE RUBY LASER.

W. W. Clendenin (Westinghouse Electric Corp., Bettis Atomic Power Laboratory, Pittsburgh, Pa.). Journal of Applied Physics, vol. 35, Aug. 1964, p. 2277, 2278. 13 refs.

Presentation of results of a numerical investigation of the non-linear rate equations for the ruby laser. Large-amplitude solutions of the rate equations corresponding to the initial low value of photon density have been obtained. The damping rate for these oscillations increases with optical pump rate in contrast to the decrease found experimentally by Walsh and Kemeny. Variation of the damping rate with loss rate is also examined. The damping rate becomes the same order of magnitude as that of the usual flash lamp rate (about 10^3 sec^{-1}) for a loss rate corresponding to a rod geometry.

A64-24205

PHOTOSENSITIVE LIQUID USED AS A NONDESTRUCTIVE PASSIVE Q-SWITCH IN A RUBY LASER.

P. Kafalas, J. I. Masters, and E. M. E. Murray (Technical Operations, Inc., Technical Operations Research, Burlington, Mass.). *Journal of Applied Physics*, vol. 35, Aug. 1964, p. 2349, 2350. 6 refs.

ARPA-supported research.

Discussion of the use of a solution of cryptocyanine in methanol as a self-synchronizing, nondestructive, passive Q-switch in a ruby laser. A symmetric giant pulse of about 10 nsec width and 5 to 10 Mw peak power is produced with a standard ruby-laser system. The pulse is comparable with pulses generated by other Q-switching techniques. In the dye solution Q-switch, the dominant switching mechanism is presumed to be the optical pumping of the dye molecules.

A64-24209

RUBY LASER WITH PIEZOELECTRICALLY EXCITED VIBRATING REFLECTOR.

E. A. Gerber and E. R. Ahlstrom (U.S. Army, Electronics Research and Development Laboratories, Fort Monmouth, N.J.). *Journal of Applied Physics*, vol. 35, Aug. 1964, p. 2546, 2547. 5 refs.

Investigation of the possibility of avoiding multimoding in solid-state lasers by causing at least one reflector of the Fabry-Perot cavity to vibrate with sufficient amplitude and frequency. It is felt that this procedure could at least partially smooth out a nonuniform distribution of excited states. To verify this concept, experiments are performed with a ruby laser with detached reflectors. One reflector is a stationary dielectric mirror, and the other mirror provides the frequency sweeping mechanism. The total energy output of the laser is measured, and the power output is recorded on an oscilloscope as a function of time. It is felt that further measurements of the beam spread and the Fabry-Perot patterns will be necessary to arrive at a final conclusion as to the influence of a vibrating mirror on the mode pattern and the energy output of a solid-state laser.

A64-24210

LASER ACTION IN Xe IN TWO DISTINCT CURRENT REGIONS OF AC AND DC DISCHARGES.

G. E. Courville, P. J. Walsh, and John H. Wasko (Fairleigh Dickinson University, Physics Dept. and Research Foundation, Teaneck, N.J.). *Journal of Applied Physics*, vol. 35, Aug. 1964, p. 2547, 2548.

Note on laser action in pure Xe and He-Xe mixtures. Two different laser tubes are used. The first is a Pyrex tube with Pyrex flats serving as end windows. The second is a quartz tube fitted with quartz Brewster end windows. Two distinct current regions exhibit laser action. In the lower current region, three laser lines, oscillating simultaneously, have the same upper state. In the high-current region of operation, only the high-gain 2.026- μ line is observed.

A64-24212

GIANT PULSE LASER OPERATION BY A PASSIVE, REVERSIBLY BLEACHABLE ABSORBER.

B. H. Soffer (Union Carbide Corp., Korad Corp., Santa Monica, Calif.).

Journal of Applied Physics, vol. 35, Aug. 1964, p. 2551. 5 refs.

Note on the production of high peak-power pulses of short duration in a laser system using a passive, reversibly bleachable, absorbing dye. The dye molecules, which initially absorb light at the laser wavelength, are rapidly bleached when ordinary laser action begins. The cavity Q is increased and the stored energy is released in a giant pulse. The dye has a high absorption cross section per molecule at the laser wavelength. Preliminary measurements indicate that the giant pulse is preceded by ordinary laser light with less than 1% as much energy per pulse.

A64-24213

MEASUREMENT OF FRESNEL DRAG WITH THE RING LASER.

W. M. Macek, J. R. Schneider, and R. M. Salamon (Sperry Rand Corp., Sperry Gyroscope Co., Electro-Optics Group, Great Neck, N.Y.).

Journal of Applied Physics, vol. 35, Aug. 1964, p. 2556, 2557. 6 refs.

Measurement of the Fresnel drag in solid, liquid, and gaseous media with a ring laser. Using a ring laser, phase changes in optical length can be observed as the difference between resonant frequencies for oppositely directed waves. The Fresnel drag effect is utilized in a ring laser to produce a frequency mode split for moving solid, liquid, and gaseous media. The ring laser uses the 1.153 μ line of a He-Ne gas system in a square optical resonator, with gas tubes in three legs and the fourth leg containing the moving medium. The frequency split for each medium is plotted as a function of the velocity of the moving medium. The liquid (CCl₄) and the gas (air) motion are in the form of a flow, while the solid (quartz) is rotated to provide the motion. The effect of the Earth's rotation is seen to have a significant effect on the measurements.

A64-24514

SOME RESULTS OF AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF A MAGNETIC FIELD ON THE RADIATION SPECTRUM OF A RUBY LASER.

A. M. Kubarev and V. I. Piskarev (Gor'kovskii Gosudarstvennyi Universitet, Radiofizicheskii Institut, Gorki, USSR). (*Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki*, vol. 46, Feb. 1964, p. 508-510.)

Soviet Physics - JETP, vol. 19, Aug. 1964, p. 345-348. 7 refs. Translation.

[For abstract see Accession no. A64-19349 14-25]

A64-24516

ON THE MECHANISM OF OPERATION OF A RAMAN LASER.

V. T. Platonenko and R. V. Khokhlov.

(*Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki*, vol. 46, Feb. 1964, p. 555-559.)

Soviet Physics - JETP, vol. 19, Aug. 1964, p. 378-381. 7 refs. Translation.

A64-24518

ON THE THEORY OF STIMULATED COMBINATION (RAMAN) RADIATION.

V. M. Fain and E. G. Iashchin (Gor'kovskii Gosudarstvennyi Universitet, Radiofizicheskii Institut, Gorki, USSR).

(*Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki*, vol. 46, Feb. 1964, p. 695-709.)

Soviet Physics - JETP, vol. 19, Aug. 1964, p. 474-483. 17 refs. Translation.

[For abstract see Accession no. A64-19353 14-25]

A64-24701

MEASUREMENT OF MICROWAVE SHOT-NOISE REDUCTION FACTOR BY LASER LIGHT INDUCED PHOTOEMISSION.

S. Saito and Y. Fujii (Tokyo, University, Institute of Industrial Science, Tokyo, Japan).

IEEE, Proceedings, vol. 52, Aug. 1964, p. 980.

Research supported by Japan Telegraph and Telephone Corp., Electrical Communications Laboratory.

Description of the measurement of the shot-noise reduction factor at microwave frequencies. A block diagram of the system is presented. An equation is given for the determination of the reduction factor based on measurements of microwave power and the dc photocurrent. A ruby laser is used as a strong source of microwave-modulated light. The reduction factor has been measured for S-band low-noise traveling-wave tubes. The results are presented and are shown to agree with theoretical predictions.

made by previous workers. An explanation is given for the decrease of shot noise at a specific frequency.

A64-24705

DETECTION OF THE TRANSVERSE DOPPLER EFFECT WITH LASER LIGHT.

Dan Censor (Technion - Israel Institute of Technology, Faculty of Electrical Engineering, Haifa, Israel).

IEEE, Proceedings, vol. 52, Aug. 1964, p. 987.

Discussion of a communication regarding detection of transverse Doppler effect. Distinction is made as to phenomena mentioned. A solution is given, as well as an alternate method of detection.

A64-24723

P-N JUNCTION LASERS.

G. Burns and M. I. Nathan (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

IEEE Proceedings, vol. 52, July 1964, p. 770-794. 162 refs.

Review of p-n junction injection lasers. The literature published up to November 1963, in addition to a number of preprints, is thought to be rather completely covered. Following an introduction, background calculations and ideas are presented which include: methods of obtaining negative temperatures, indirect vs direct band gap semiconductors, and quasi-Fermi levels. Other topics and sub-topics are: efficient light emission (discussing diodes and fluorescence of GaAs and similar compounds); p-n junction lasers: experimental (discussing initial observations, fabrication techniques, spectral properties, spatial properties, temperature effects, external and internal efficiency, heating effects, and magnetic field effects); junction lasers: theoretical (describing the threshold relation, guiding of modes, spectral calculations, and lifetimes); and device aspects. Recent results are also covered.

A64-24731

ZERO FIELD MILLIMETER MASER.

W. E. Hughes (Westinghouse Electric Corp., Aerospace Div., Applied Physics Group, Baltimore, Md.) and R. E. Deal (USAF, Systems Command, Aeronautical Systems Div., Avionics Laboratory, Electronic Technology Div., Wright-Patterson AFB, Ohio).

IEEE, Proceedings, vol. 52, July 1964, p. 857.

Contract No. AF 33(657)-10472.

Discussion of a maser which is said to differ in two respects from those previously reported; the frequencies involved are such that $h\nu_{ij} = (E_j - E_i) - kT$ and the maser operation occurs between the upper two doublets - i.e., $\pm 5/2$, $\pm 3/2$ of the ground state spin levels. Rate equations are presented for three-level operation because the iron ion in rutile was found to have its lowest ground state split into three doublets by the crystal field. These doublets are separated by 43,268 and 81,375 Gc. A 0.125-in. cube was used which allowed resonances at about 20-Mc intervals at the signal frequency. The experiments were performed in a conventional millimeter wave spectrometer and under cryogenic conditions.

A64-24874

HOLLOW METALLIC AND DIELECTRIC WAVEGUIDES FOR LONG DISTANCE OPTICAL TRANSMISSION AND LASERS.

E. A. J. Marcatili and R. A. Schmelzter (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

Bell System Technical Journal, vol. 43, July 1964, p. 1783-1809. 16 refs.

Determination of the field configurations and propagation constants of the normal modes for a hollow circular waveguide made of dielectric material or metal, for application as an optical waveguide. The increase of attenuation due to curvature of the axis is also determined. The attenuation of each mode is found to be proportional to the square of the free-space wavelength λ and inversely proportional to the cube of the cylinder radius a . For a hollow dielectric waveguide made of glass with $v = 1.50$, $\lambda = 1 \mu$, and $a = 1$ mm, an attenuation of 1.85 db/km is predicted for the minimum-loss mode, EH_{11} . Dielectric materials are shown to be very attractive as guiding media for gaseous amplifiers and oscillators, not

only because of the low attenuation, but also because the gain per unit length of a dielectric tube containing He-Ne "masing" mixture at the right pressure can be considerably enhanced by reducing the tube diameter. It is noted that the hollow metallic circular waveguide appears to be very attractive as a transmission medium for long-distance optical communication.

A64-25143

FREQUENCY STABILIZATION OF SINGLE MODE GAS LASERS.

A. D. White, E. I. Gordon, and E. F. Labuda (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

Applied Physics Letters, vol. 5, Sept. 1, 1964, p. 97, 98. 5 refs.

Description of laser stabilization in which the laser-transition profile is used in a new way to obtain a sensitive frequency discriminator. It is stated that, basically, the scheme involves splitting the atomic absorption (or gain) profile by means of a magnetic field or the use of isotopes. The splitting is done in an external discharge cell through which the laser beam is transmitted. The two methods in which a frequency discriminator is formed are described. It is stated that, in both methods, the transmitted beam will contain an amplitude modulation at the switching frequency proportional to the algebraic difference of the two absorption profiles. The homodyne detection of the modulated laser beam using the switching signal as a reference yields a conventional discriminator characteristic.

A64-25146

RAMAN LASER ACTION IN MIXED LIQUIDS.

J. A. Calviello and Z. H. Heller (Cutler-Hammer, Inc., Airborne Instruments Laboratory Div., Melville, N.Y.).

Applied Physics Letters, vol. 5, Sept. 1, 1964, p. 112, 113. 5 refs.

Description of experiments performed upon Raman lasers, with separate cells containing different molecular species within the laser cavity, as well as liquid mixtures in the same cell. It is stated that two simultaneous Raman laser oscillations were always observed in acetone-benzene, toluene-benzene, and fluorobenzene-benzene mixtures. It is noted that the simultaneous generation of two coherent, closely spaced, high power signals is of interest for optical mixing experiments, because the separation of the two Raman frequencies is temperature-independent and the beams are collinear with the laser beam.

A64-25470

NONLINEAR OPTICS.

R. W. Terhune (Ford Motor Co., Dearborn, Mich.).

International Science and Technology, Aug. 1964, p. 38-47.

Description of some experiments performed in the field of nonlinear optics. It is stated that, when light becomes as intense and as monochromatic as waves at RF, it will do all of the things radio waves do under similar circumstances. Moreover, through resonant nonlinear process, the frequency of the light can be shifted up or down by a characteristic absorption frequency of the material. It is noted that coupling this effect with the doubling and mixing capabilities, any frequency of light can be converted to any other frequency with up to 50% efficiency.

A64-25509

ON THE FILAMENTOUS MODES OF A CRYSTAL LASER [SUR LES MODES FILAMENTAIRES D'UN LASER A CRISTAL].

François Berstein, François Petit, and Renée Bernard.

Academie des Sciences (Paris), Comptes Rendus, vol. 259, no. 3, July 20, 1964, p. 537-540. In French.

Presentation of the numerical expression, in very simple cases, for the structure of the filamentous modes existing in a ruby laser. Modes are obtained with a width of the order of $2W_0$, which are appreciably independent of the location of the laser defect. It is stated that filamentous modes present different oscillation thresholds and appear progressively with the increase of pumping.

A64-25669

EVAPORATION COEFFICIENTS FROM EXPOSURE OF A SOLID TO LASER RADIATION.

S. S. Penner (California, University, Dept. of Aerospace and Mechanical Engineering Sciences, La Jolla, Calif.).

AIAA Journal, vol. 2, Sept. 1964, p. 1664-1666. 5 refs.

Grant No. DA-ARO(D)-31-124-G504.

Report of an investigation. A relationship is presented between the evaporation coefficient and the linear regression rate for a solid. The former term is obtained by using evaporation-rate measurement of a solid when exposed to a monochromatic laser beam. A schematic diagram illustrating the proposed experimental technique is given. A relation is derived which yields the depth of regression. This depth is shown to be observable under the conditions of the experiment.

A64-25763

QUANTUM STATISTICS AND LASERS.

J. P. Gordon (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Journal of Research, Section D - Radio Science, vol. 68D, Sept. 1964, p. 1031-1033. 8 refs.

Consideration of the quantum statistical features of a linear process of amplification or attenuation. The results are then used to estimate the spontaneous fluctuations of a class of laser oscillators. The question of a quantum-mechanical information theory is discussed. It is stated that the general problem of writing quantum mechanics into information theory is a relatively untouched area. The equation proposed by Gordon as a quantum formulation, although believed to be correct by the author, has not been proved, nor has any other expression been proposed.

A64-25768

HIGH-ORDER TRANSVERSE MODES IN GaAs LASERS.

Kurt Weiser and Frank Stern (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

Applied Physics Letters, vol. 6, Sept. 15, 1964, p. 115, 116. 9 refs. Army-supported research.

Report of observed transverse modes in GaAs injection lasers having a wide, high-resistivity p-type layer between low-resistivity n- and p-type layers. Evidence for high-order modes is said to come from the near-field radiation pattern of the diode face, which has many bright stripes parallel to the junction, and from the far-field pattern, which shows two main beams about 30° apart in the plane perpendicular to the junction plane and to the diode face. Conditions favoring high-order modes are described, and observed and calculated far-field intensities are graphed.

A64-25769

³He NUCLEAR ZEEMAN MASER.

H. G. Robinson and Than Myint (Harvard University, Cambridge, Mass.).

Applied Physics Letters, vol. 6, Sept. 15, 1964, p. 116-118. Navy-NSF-supported research.

Report of a new type of maser with a resonance linewidth said to be much narrower than previously obtainable. The maser is indicated to operate continuously on the nuclear Zeeman transition ($m_1 = +1/2$) - ($m_1 = -1/2$) in the ground state of optically pumped He-3. According to the authors, this is the first time that He-3 has been utilized in such a maser, and in addition, the device is the first nuclear Zeeman maser to operate with a gas. The optical pumping process is reportedly similar to that described by Colegrove, Schearer, and Walters. A technique for avoiding the problem of collision broadening is described, and a schematic diagram and configuration description of the device are included. The tuned circuit coupled to the nuclear magnetization in the observation region reportedly had a Q of 200. The polarization was reportedly determined by comparing the initial signal amplitude with the amplitude from a similar nuclear magnetic resonance (NMR) induction signal from protons in Benzene at a field of 32 gauss. Characteristics of one sample are given and the effects of motional narrowing are described.

A64-25771

INTERNAL GATING OF OPTICALLY PUMPED, HIGH-GAIN, SOLID-STATE LASERS.

G. E. Danielson, Jr. and A. J. DeMaria (United Aircraft Corp., Research Laboratories, East Hartford, Conn.).

Applied Physics Letters, vol. 6, Sept. 15, 1964, p. 123-125. 6 refs. Contract No. DA-12-020-AMC-0170(A).

Reported observations of oscillations of a 53-cm long, 0.84-cm diam. Nd-doped barium crown glass laser rod at 50% above threshold with and without 900-kc ultrasonic excitation. Laser modulation by propagation of ultrasonic waves directly within the laser crystal is believed to have advantages over the magnetic field modulation technique and the technique which introduces lossy external elements into the optical feedback path. Using the ultrasonic technique, a gating repetition rate at the sonic frequency or at twice the sonic frequency is believed to be obtainable depending on the parallelism of the reflectors. The experiments reportedly have demonstrated that the periodic fluctuation of the refractive index resulting from the propagation of focused ultrasonic energy within a solid-state laser medium can be utilized as a Q-spoiler to gate the output of such a laser. Photographs of acoustical standing waves and of oscillations with and without excitation are included, and a drawing of the experimental arrangement is presented.

A64-25820

OFF-AXIS FEEDBACK MODES IN A THREE-MIRROR LASER SYSTEM.

Allan I. Carswell and Armand L. Waksberg (RCA Victor Co., Ltd., Research Laboratories, Montreal, Canada).

Canadian Journal of Physics, vol. 42, Sept. 1964, p. 1829-1833. 5 refs.

Research supported by Canada, Directorate of Industrial Research.

Description of an arrangement of a helium-neon laser system in which a third mirror is employed to reflect a portion of the laser output back into the laser. It is shown that significant feedback effects can be obtained for certain mirror configurations even when the third mirror is tilted at an appreciable angle to the laser axis. The off-axis modes generated are seen to offer a method of controlling the feedback level in the three-mirror system by a very simple angular adjustment of the third mirror.

A64-25834

AVERAGED LASER EQUATIONS AND THEIR STATIONARY SOLUTIONS.

L. A. Ostrovskii and E. I. Iakubovich (Gor'kovskii Gosudarstvennyi Universitet, Radiofizicheskii Institut, Gorki, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 46, Mar. 1964, p. 963-969.)

Soviet Physics - JETP, vol. 19, Sept. 1964, p. 656-660. 9 refs. Translation.

A64-25872

SPECTRAL OUTPUT OF SEMICONDUCTOR LASERS.

H. Stutz, C. L. Tang, and J. M. Lavine (Raytheon Co., Research Div., Waltham, Mass.).

Journal of Applied Physics, vol. 35, Sept. 1964, p. 2581-2585. Contract No. AF 19(628)-3862.

Analysis of the extent to which nonuniform distributions of electrons and holes may be produced in a semiconductor laser and of how these nonuniform distributions encourage the simultaneous oscillations of other modes. The smoothing effect of electron and hole diffusion on nonuniform carrier distributions is studied for transverse modes. Calculations are made for multimode oscillations in GaAs lasers, and the results are compared with those of experiments.

A64-25886

THEORY OF PHOTOELECTRIC DETECTION OF LIGHT FLUCTUATIONS.

L. Mandel (London, University, Imperial College of Science and Technology, Dept. of Physics, London, England), E. C. G. Sudarshan (Brandeis University, Dept. of Physics, Waltham, Mass.), and E. Wolf (Rochester, University, Dept. of Physics and Astronomy, Rochester, N. Y.).

Physical Society, Proceedings, vol. 84, Sept. 1964, p. 435-444. 39 refs.

Army-supported research.

Presentation of the basic formulas governing the fluctuations of counts registered by photoelectric detectors in an optical field. The treatment, which has its origin in Purcell's explanation of the Hanbury Brown-Twiss effect, is shown to apply to any quasi-monochromatic light, whether stationary or not, and whether of thermal origin or not. The presentation of the classical wave amplitude of the light by Gabor's complex analytic signal appears naturally in this treatment. It is shown that the correlation of counts registered by N separate photodetectors at N points in space is determined by a $2N$ th order correlation function of the complex classical field. The variance of the individual counts is shown to be expressible as the sum of terms representing the effects of classical particles and classical waves, in analogy to a well-known result of Einstein relating to black-body radiation. It is noted that, since the theory applies to correlation effects obtained with any type of light, it applies, in particular, to the output of an optical maser, although, for a maser operating on one mode, correlation effects are likely to be very small.

A64-25895

ON THE MEASUREMENT OF THE SPATIAL COHERENCE OF A LASER BEAM.

M. Bertolotti, B. Daino (Fondazione U. Bordini, Istituto Superiore P. T., Rome, Italy), and D. Sette (Roma, Università, Istituto di Fisica, Rome, Italy).

Nuovo Cimento, vol. 33, Sept. 16, 1964, p. 1705-1709. 7 refs.

Description of an experimental apparatus which makes it possible to measure quantitatively the spatial coherence of various kinds of sources. The numerical values obtained for the spatial coherence of a helium-neon laser are presented. The degree of coherence is said to vary across the beam. It is noted that preliminary results show that coherence depends on mode type.

A64-26036

MUTUALLY QUENCHED INJECTION LASERS AS BISTABLE DEVICES.

G. J. Lasher and A. B. Fowler (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

IBM Journal of Research and Development, vol. 8, Sept. 1964, p. 471-475.

Contract No. DA-36-039-SC-90711.

Discussion of the quenching process and presentation of a definition for quenching ratio. When the coherent output of one laser is passed through the active region of a second, the second laser is stimulated to emit in the same direction as the incident light. The power added to the amplified incident light is subtracted from the power in the normal lasing mode or modes of the second laser. This process is referred to as quenching, and a quenching ratio is defined as the power extracted from the quenched laser divided by the incident power, noting that for identical lasers the incident power will be equal to the power available for stimulated emission in the quenched laser. The quenching of one laser by the coherent light of another has reportedly been observed for GaAs injection lasers and for neodymium glass lasers. Some simple expressions are derived for the quenching ratio in certain ideal situations. The obtained expressions are compared with the results of some quenching experiments reported by one of the authors. Additional topics include: stable states of operation of lasers quenching each other with quenching ratios somewhat greater than unity and configuration, construction, and principles of operation of bistable devices. It is thought possible that logic or memory systems using optically coupled elements may someday be realized.

A64-26083

INTERFERENCE BETWEEN WAVEFRONTS ROTATED OR REVERSED WITH RESPECT TO EACH OTHER AND ITS RELATION TO SPATIAL COHERENCE.

M. V. R. K. Murty (Rochester, University, Institute of Optics, Rochester, N. Y.).

(Optical Society of America, Spring Meetings, Washington, D. C., Apr. 1964.)

Optical Society of America, Journal, vol. 54, Oct. 1964, p. 1187-1190.

NASA-supported research.

Report of an investigation. A Twyman-Green interferometer is used with either a right-angle prism or a cube-corner prism in one arm. This brings about a left-right reversal of one of the interfering beams. The situation is analyzed, and suitable conditions are derived under which fringes of equal thickness can be seen. Diagrams illustrating the fringes obtained for various conditions and slits are presented. Use of a visible gas laser as a source of illumination is discussed.

A64-26109

ZEEMAN EFFECT AND RUBY LASER POLARIZATION.

A. S. Badger (Houston, University, Houston, Tex.) and T. A. Rabson (William Marsh Rice University, Dept. of Electrical Engineering, Houston, Tex.).

IEEE, Proceedings, vol. 52, Sept. 1964, p. 1047, 1048.

Grant No. NsG-66-59.

Report of an investigation of the possibility of modulating the amplitude of a ruby-laser beam by changing the linear polarization with a controllable magnetic field. The marked difference in the matrix factor for varied polarizations shows the strong effect of the crystal electric field on the chrome ion transitions, and this reportedly made the prospects of altering the polarization by application of a magnetic field rather poor. A detailed series of experiments was made to determine whether uniform magnetic fields up to 8000 gauss would alter the polarization of the laser output. The output from the front of the laser was normalized by comparing it with the output from the rear because the total output was found to vary considerably despite careful timing of flashes and the use of a regulated power supply to charge the storage capacitors. The results of the experiments showed no change in the polarization of the output for uniform fields perpendicular to the axis of the laser with magnitudes up to 8000 gauss for either the 0° rod or the 90° rod. The effect of magnetic fields on the microwave beats in the output of a ruby laser was also investigated. The only reproducible effect observed was that the amplitude of the microwave beating was considerably reduced by the application of a magnetic field of sufficient intensity to counteract the magnetic field produced by the exciting current in the linear flash tube. Work is reportedly continuing on other solid-state materials which do not present the formidable obstacle of a powerful crystal field, as does ruby.

A64-26110

DEMODULATION OF PHASE-MODULATED OPTICAL MASER BEAM BY AUTOCORRELATION TECHNIQUE.

Shigebumi Saito and Tatsuya Kimura (Tokyo, University, Institute of Industrial Science, Tokyo, Japan).

IEEE, Proceedings, vol. 52, Sept. 1964, p. 1048. 8 refs.

Presentation of calculations demonstrating that an autocorrelator followed by a square-law detector can be used as a demodulator of phase-modulated laser beams. Preliminary experiments are reported to verify the derived mathematical equations. A Twyman interferometer was used to provide the necessary time delay, and a He-Ne gaseous optical maser (6328 \AA) was phase-modulated at a frequency of 1680 Mc, using a KDP crystal contained in a TM_{010} mode cavity. A photocathode TWT was used as a square-law detector. When one of the branches of the interferometer is blocked, as well as when the total beam is blocked, the detected output of the TWT reportedly vanishes. This reportedly can only happen when the phase-modulated beam is demodulated by an autocorrelation technique.

A64-26111

USE OF DIELECTRIC ETALON AS A REFLECTOR FOR Q-SWITCHED LASER OPERATION.

H. Pawel (Newark College of Engineering, Newark, N. J.), J. R. Sanford, J. H. Wenzel (General Electric Co., Ithaca, N. Y.), and G. J. Wolga (Cornell University, Ithaca, N. Y.).
IEEE, Proceedings, vol. 52, Sept. 1964, p. 1048, 1049.

Report on the operation of a 6-in. Q-switched ruby laser using a glass etalon reflector for a period of over 100,000 laser pulses. Use of the etalon reflector is indicated to have resulted in a lower threshold and narrower beam divergence. The Q-switched laser energy output was reportedly on the order of 1 joule. This extended use is said to have resulted in no visible degradation of the etalon. The etalon method was also used in the test of smaller Q-switched laser rods, and comparisons were made with the spinning Porro prism and the multilayer dielectric reflector techniques. Two tables are included which contain information on the threshold energies (both pulsed and Q-switched) for various combinations of etalon, flashlamp, and rod size.

A64-26112

MERCURY-RARE GAS VISIBLE-UV LASER.

H. G. Heard and J. Peterson (Energy Systems, Inc., Palo Alto, Calif.).
IEEE, Proceedings, vol. 52, Sept. 1964, p. 1049, 1050.

Report of observed simultaneous laser action in the visible and UV regions in the excited states of mercury and a rare gas (argon), when the two were combined in the same plasma tube. Frequencies and transitions were determined and tabulated for emission lines obtained for Ar II and Hg II. The plasma tube used in the experiments reportedly had a 5-mm bore and a 150-cm length and was of the cold-cathode type having mercury electrodes. The tube was filled with argon at partial pressures in the 10^{-3} -torr range. Low pressures and high current densities are said to enhance excitation of the UV and short-wavelength lines. The effects of partial pressure, mercury temperature, peak current, and bore size were investigated. The use of dielectric, aluminum, and gold mirrors is also discussed.

A64-26113

ORANGE THROUGH BLUE-GREEN TRANSITIONS IN A PULSED-CW XENON GAS LASER.

H. G. Heard and J. Peterson (Energy Systems, Inc., Palo Alto, Calif.).
IEEE, Proceedings, vol. 52, Sept. 1964, p. 1050.

Report of laser action noted for 11 high-gain transitions in the excited spectrum of pure xenon. The wavelengths of the reported lines are said to agree closely with prominent lines in the Xe II spectrum. The plasma tube used has a 3-mm bore and a plasma length of 130 cm. Laser action was noted in the pressure range from 1 to 100 millitorr, and the longer-wavelength transitions were always strongest at higher pressure. Quasi-CW laser action (100-200 μ sec) has reportedly been obtained for most of the reported transitions. A tentative transition assignment for the observed wavelengths is given in a table, but the assignments for two of the transitions are reportedly not clear at this time. It is suggested that they may belong to the Xe III series.

A64-26246

THE INJECTION LASER [DER INJEKTIONS LASER].

Waldemar von Münch (Internationale Büro-Maschinen GmbH, IBM-Laboratorien, Böblingen/Württemberg, West Germany).
VDI Zeitschrift, vol. 106, Aug., pt. 3, 1964, p. 1196-1198, 5 refs. In German.

Study of the characteristics of an injection laser, showing that laser action is achieved in p-n junctions of some semiconductor materials such as gallium arsenide. The pumping energy which causes the population inversion is obtained directly from the current flowing through the diode. The emitted electric radiation is modulated by varying the diode current.

A64-26319

AMPLIFICATION IN A FIBER LASER.

Charles J. Koester and Elias Snitzer (American Optical Co., Southbridge, Mass.).
(Optical Society of America, Spring Meeting, Jacksonville, Fla., 1963.)

Applied Optics, vol. 3, Oct. 1964, p. 1182-1186. 9 refs. USAF-supported research.

Report of an investigation. The oscillation condition in a laser is discussed, and a relation for the gain is derived. The procedure followed in the experiments is described. Oscilloscope traces are presented that show fiber laser amplification and amplification at several pumping levels. Amplification obtained with normal fiber ends is considered, as well as methods of eliminating feedback. It is found that if the ends of the fiber are beveled, then oscillations are prevented, thereby effectively eliminating feedback. The gain is found to be a strong function of the pump power and of the time during the pulse at which the gain is measured. Gains as high as 5×10^4 have been observed in a 1-m fiber.

A64-26320

LASER INTERFEROMETRY OF PENTAPRISMS.

Robert M. Zoot (Litton Systems, Inc., Guidance and Control Systems Div., Woodland Hills, Calif.).
Applied Optics, vol. 3, Oct. 1964, p. 1187-1189.

Discussion of a procedure. The optical arrangement of the test components is illustrated, and the procedure used for the setting and testing of the surfaces is described. Use is made of a 6328-Å gas laser, the plates from a Fabry-Perot etalon, and an autocollimator of 1/2" resolution. Pentaprism accuracy at 1" of arc or better may be accomplished with high reliability. Due to the very high intensity and beam coherence of the laser, large pentaprisms and mirror systems may be tested.

A64-26321

GAS LASER PREAMPLIFIER PERFORMANCE.

W. B. Bridges and G. S. Picus (Hughes Aircraft Co., Research Laboratories, Malibu, Calif.).
Applied Optics, vol. 3, Oct. 1964, p. 1189, 1190. 9 refs.

Report of an investigation. A 16-db improvement in the minimum detectable signal of two fast IR detectors (Philco types L4530, L4540) at 3.5- μ wavelength is obtained using a xenon gas laser preamplifier. The detector characteristics are presented, and the experimental arrangement used for the measurement is illustrated and described along with the experimental procedure. The noise behavior of the photodiodes is reviewed with respect to the range of signal levels and information bandwidths to which the behavior described will apply. The results of this experiment indicate that the inversion ratio must be high and that the improvement in minimum detectable signal obtained will depend on the properties of the detector.

A64-26322

A SIMPLE WAY OF DEMONSTRATING THE PHASE REVERSALS IN THE TEM₁₀, TEM₂₀, TEM₃₀ MODES OF A GAS LASER SOURCE.
 M. V. R. K. Murty (Rochester, University, Institute of Optics, Rochester, N. Y.).

Applied Optics, vol. 3, Oct. 1964, p. 1192-1194. 6 refs.

Description of a procedure. Young's double-source experiment is referred to as a means of demonstrating the phase shift of 180° between the lobes of a given mode pattern. Use is made of a lateral shearing interferometer to demonstrate the phase reversal. A schematic diagram of the equipment arrangement is presented, and the procedure used is discussed.

A64-26395

MODE OF OPERATION AND APPLICATIONS OF LASER [WIRKUNGSWEISE UND ANWENDUNGEN DES LASERS].

N. Neuroth (Jenaer Glaswerke Schott und Gen., Mainz, West Germany).

Chemie-Ingenieur-Technik, vol. 36, Sept. 1964, p. 947-956. 71 refs. In German.

Discussion of the mode of operation, types, and applications of solid and gaseous lasers. Characteristics of Cr^{+3} , Pr^{+3} , Nd^{+3} , Sm^{+2} , Gd^{+3} , Dy^{+2} , Ho^{+3} , Er^{+3} , Tm^{+2} , Tm^{+3} , Yb^{+3} , U^{+3} , GaAs, $\text{GaAs}_x\text{P}_{1-x}$, $\text{In}_x\text{Ga}_{1-x}\text{As}$, InAs, InP, InSb, Eu^{3+} in benzoylacetate, and benzophenone + naphthalene, as active laser substances, are tabulated. Application of lasers in spectroscopy, as an extremely monochromatic source of rays, in microscopy as the illumination source, in Raman spectroscopy, distance measuring, and photochemical reactions is indicated.

A64-26437

MANY-ELEMENT LASERS.

R. Pratesi, G. Toraldo di Francia (Firenze, Università, Istituto di Fisica Superiore, Florence, Italy) and L. Ronchi (Centro Microonde, Florence, Italy).

Nuovo Cimento, vol. 34, Oct. 1, 1964, p. 40-50. 18 refs.

USAF-supported research.

Presentation of theoretical and experimental results obtained with a solid-state laser consisting of many active elements in series. A statistical treatment is developed to derive the oscillation conditions. Asymptotic expressions are given of the threshold gain/unit length holding either for a very large number of elements or for inner surface reflectivities close to 1. It is found that lossless reflections at the inner surfaces can increase the cavity Q with respect to a one-element laser of the same active length. It is stated that preliminary experiments with five- and ten-element lasers demonstrate the mode-selection property of the many-element laser and show the tendency of the system to produce a "quasi-continuous" emission. The possibility of obtaining optical correction of the defects inherent in the solid material has also been demonstrated.

A64-26444

THE PHASE STRUCTURE OF THE OUTPUT BEAM OF A RUBY LASER.

N. G. Bondarenko, I. V. Eremina, and V. I. Talanov (Gor'kovskii Gosudarstvennyi Universitet, Radiofizicheskii Institut, Gorki, USSR).

(Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 46, Apr. 1964, p. 1500-1502.)

Soviet Physics - JETP, vol. 19, Oct. 1964, p. 1016, 1017. Translation.

[For abstract see Accession no. A64-19441 15-25]

A64-26510

OBSERVATION OF THOMSON AND CO-OPERATIVE SCATTERING OF RUBY LASER LIGHT BY A PLASMA.

A. W. DeSilva, D. E. Evans, and M. J. Forrest (United Kingdom Atomic Energy Authority, Atomic Energy Research Establishment, Culham Laboratory, Culham, Berks., England).

Nature, vol. 203, Sept. 26, 1964, p. 1321, 1322. 5 refs.

NSF-supported research.

Report of an experiment in which the correct choice of plasma parameters permits detection of the mode where the parameter, α , characterizing the wavelength spectrum resulting from the scattering of monochromatic light directed on to a plasma, is much less than 1, and also of the collective mode in the same plasma that the same powerplant, operating in the ramjet mode, can be used to cruise in air-breathing aircraft continuously at these speeds. Another advantage of the turbojet over the ordinary gas turbine is its lightweight powerplant (about one-third the turbine-engine weight for the same thrust), which more than offsets the higher fuel consumption for accelerating flight. The fundamentals of the accelerating flight plan are examined, and the design, performance, and weight characteristics of the turbojet engine are discussed. The temperatures at various parts of the engine are compared to the corresponding temperatures of a state-of-the-art gas turbine.

A64-26692

INJECTION LASERS.

Robert W. Keyes (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).
Industrial Research, vol. 6, Oct. 1964, p. 46-51, 54, 55.

Review of the development and applications of semiconductor lasers from the first discovery of p-n junction electroluminescence by Lossev in 1923. Advantages of the injection laser are seen to be its rapid light-output response to electrical pulses; its small size, facile fabrication, and low cost; the ease of operation, requiring simply the passage of an electric current for activation; and its efficiency in converting electrical power to light. Disadvantages are that the injection laser's small size limits its power and increases the angular divergence of the emitted light. Furthermore, best operation occurs at extremely low cryogenic temperatures.

W. M. R.

A64-26740

ELECTRON DENSITY IN A PULSED HELIUM-NEON LASER.

G. T. McNice (Martin Marietta Corp., Martin Co., Orlando Div., Orlando, Fla.).

IN: INTERNATIONAL CONVENTION ON MILITARY ELECTRONICS, 8TH, WASHINGTON, D. C., SEPT. 14-16, 1964, CONFERENCE PROCEEDINGS.

Conference sponsored by the Military Electronics Group of the Institute of Electrical and Electronics Engineers.

Edited by B. J. Goldfarb.

North Hollywood, Western Periodicals Co., 1964, p. 41, 42. 6 refs.

Report of a study of the operation of a helium-neon laser at 1.15μ as it relates to the excitation and de-excitation processes of the metastable 2^3S state of helium. One of the excitation processes is indicated to be the exchange interaction $\text{He}(2^1S) + e^- \rightarrow \text{He}(2^3S) + e^- + 0.79 \text{ eV}$, which occurs at a rate proportional to the electron density. In order to determine the significance of the process, it is thought necessary to obtain an experimental determination of the electron density in the laser tube. This determination was obtained by inserting the laser into a microwave interferometer and recording the complex attenuation of the signal as a function of time after the excitation pulse. This is then related to the electron density through the complex propagation constant of the medium. The required equations are derived, and experimental results are portrayed graphically as traces of electron density vs time and oscilloscope pattern vs time.

D. H.

A64-26741

OPTICAL DOPPLER SIGNALS FROM DIFFUSE REFLECTING TARGETS.

V. J. Corcoran and F. M. Reiner (Martin Marietta Corp., Martin Co., Orlando Div., Orlando, Fla.).

IN: INTERNATIONAL CONVENTION ON MILITARY ELECTRONICS, 8TH, WASHINGTON, D. C., SEPT. 14-16, 1964, CONFERENCE PROCEEDINGS.

Conference sponsored by the Military Electronics Group of the Institute of Electrical and Electronics Engineers.

Edited by B. J. Goldfarb.

North Hollywood, Western Periodicals Co., 1964, p. 43-45.

Discussion of a comparative analysis of an optical analog of a Doppler radar and a system using a modulated laser carrier in which the modulation is extracted after the envelope in the optical wave has been detected. An investigation is conducted of a suggestion that the coherence of the optical carrier wave is lost when the light beam is reflected from a diffuse surface such as the Earth and that, as a result, in a system using heterodyne detection, an additional loss is suffered beyond the loss in intensity caused by reflection from a diffuse surface. A worst-case problem is considered theoretically and experimentally as a check on this conjecture. It is thought safe to conclude that the superheterodyne system under the conditions specified is always superior to the envelope detection for weak signals. The theoretical and experimental results are reported to tend to dispel the idea that reflection from a diffuse surface degrades the heterodyne signal beyond that due to loss in intensity. Consequently, it is believed that the system which detects the optical Doppler is superior to the carrier-modulated system in detecting weak signals from a target.

D. H.

A64-26742

MEASUREMENT OF HIGH POWER OUTPUT FROM A HE-NE PULSED GAS LASER EMPLOYING AN EXIT MIRROR OF OPTIMUM REFLECTIVITY.

J. Goldsmith, E. H. Byerly, and A. A. Vuylsteke (Martin Marietta Corp., Martin Co., Orlando Div., Orlando, Fla.).

IN: INTERNATIONAL CONVENTION ON MILITARY ELECTRONICS, 8TH, WASHINGTON, D. C., SEPT. 14-16, 1964, CONFERENCE PROCEEDINGS.

Conference sponsored by the Military Electronics Group of the Institute of Electrical and Electronics Engineers. Edited by B. J. Goldfarb.

North Hollywood, Western Periodicals Co., 1964, p. 46-49.

Report of an observed peak power of over 300 watts measured at the 1.1177- μ transition. The average power of the laser is said to vary with the repetition rate to over 600 mw. at which point the power output drops off. The output power was achieved with a laser tube of 3-cm ID and 130-cm length with Brewster angle plates and external plane mirrors. Optimization of output power was accomplished by using a variable-reflectivity mirror arrangement. The measured output power was essentially unchanged whether a single-dielectric coated mirror with the same reflectivity as the variable-reflectivity mirror was used or the variable-reflectivity mirror arrangement itself. The chief factors critically affecting the power output of a pulsed He-Ne gas laser are discussed, including neon-to-helium ratio, total pressure, tube dimensions, cavity configuration, excitation levels, and plasma instabilities. The level of power presently achieved was reportedly not accomplished with all factors optimized; when this has been done, it is believed that the output power level will be increased by a factor of two or more.

D. H.

A64-26743

PULSE MODULATION OF AN ELECTRON INJECTION LASER TRANSMISSION SYSTEM.

E. J. Schiel, E. C. Bullwinkel, R. R. Gammarino, J. R. Armara, and R. E. Webb (U.S. Army, Electronics Research and Development Laboratories, Fort Monmouth, N. J.).

IN: INTERNATIONAL CONVENTION ON MILITARY ELECTRONICS, 8TH, WASHINGTON, D. C., SEPT. 14-16, 1964, CONFERENCE PROCEEDINGS.

Conference sponsored by the Military Electronics Group of the Institute of Electrical and Electronics Engineers. Edited by B. J. Goldfarb.

North Hollywood, Western Periodicals Co., 1964, p. 52-54.

Report on SNR measurements obtained for a gallium-arsenide injection laser system operating at ranges of 1 mile and 8 miles. An electron injection laser (EIL), fabricated by Korad, Inc., reportedly produced an output power of 100 mw when a 7-amp, 1-sec current pulse at an average repetition rate of 10 kbits/sec was applied. Ancillary equipment for the transmission system included a pulse generator, a two-stage transistorized pulse amplifier, and a collimating optical system. The receiver consisted of a 4-in. Questar telescope, an interference filter (to attenuate background radiation by a factor of 5000), and an RCA 7102 photomultiplier. A tektronix 445A oscilloscope and a digital-analog converter were used with the receiving equipment. The transmission of the air was assumed to be 100% and on clear days in the Spring and Summer of 1964, SNR's of 68 db and 34 db were measured at 1-mile and 8-mile ranges, respectively; 73 db and 37 db were the respective calculated values. In experiments with speech transmission, the use of a simple Delta modulation scheme is said to have produced a much higher SNR than another method; very intelligible speech was thus transmitted at 19,200 pulses/sec.

D. H.

A64-26744

A LASER MIRROR ARRANGEMENT POSSESSING CONTINUOUSLY VARIABLE REFLECTIVITY.

E. H. Byerly, G. T. McNice, and J. Goldsmith (Martin Marietta Corp., Martin Co., Orlando Div., Orlando, Fla.).

IN: INTERNATIONAL CONVENTION ON MILITARY ELECTRONICS, 8TH, WASHINGTON, D. C., SEPT. 14-16, 1964, CONFERENCE PROCEEDINGS.

Conference sponsored by the Military Electronics Group of the Institute of Electrical and Electronics Engineers.

Edited by B. J. Goldfarb.

North Hollywood, Western Periodicals Co., 1964, p. 55-57.

Description of a method for continuously varying the reflectivity of a laser mirror from zero to almost 100%. The technique reportedly uses a rotatable thin plane clear-glass mirror within the laser cavity. Total power output is obtained by measuring the sum of the two reflected beams from each mirror surface and the output beam from the dielectric coated mirror. This technique has reportedly been employed to experimentally determine the optimum mirror reflectivity (or transmissivity) required to provide maximum power output of a high-gain pulsed gas laser. Equations are derived for the equivalent reflectivity (or transmissivity) in terms of the reflectivity of the associated dielectric coated mirror, the index of refraction of the thin plane clear-glass mirror, and its angle of rotation with respect to the axis of the laser. An experimentally derived curve illustrates the variation in power output as a function of mirror rotation.

(Author) D. H.

A64-26745

TESTS OF A LASER INTERFEROMETRIC ANGLE TRACKER.

S. H. Logue (General Dynamics Corp., General Dynamics/Astronautics, San Diego, Calif.).

IN: INTERNATIONAL CONVENTION ON MILITARY ELECTRONICS, 8TH, WASHINGTON, D. C., SEPT. 14-16, 1964, CONFERENCE PROCEEDINGS.

Conference sponsored by the Military Electronics Group of the Institute of Electrical and Electronics Engineers.

Edited by B. J. Goldfarb.

North Hollywood, Western Periodicals Co., 1964, p. 58-61.

Report of an interferometric tracking system which takes advantage of the spatial and temporal coherence and the short wavelength and high degree of collimation that can be obtained with a 6328- \AA laser. A description of the configuration indicates that a laser light beam from the source being tracked illuminates two penta prisms that define the arms of the interferometer. The two penta prisms bend the rays through 90° angles and send them to a photomultiplier detector. Angular rotation of the interferometer system (or lateral motion of the remote laser) causes one interferometer arm to lengthen relative to the other, resulting in alternate constructive and destructive light interference. For a 25-in. spacing between arms and a 6328- \AA laser wavelength, a 0.5- μ radian rotation interchanges the light and dark areas of the pattern. It is this interferometric sinusoidal variation in light intensity that is used to measure angular changes. The use of the interferometer as a range tracker is described, and applications in both space and ground systems are considered.

D. H.

A64-26747

LASER PHASED ARRAYS.

L. W. Procopio, F. A. Jessen, and L. J. Brown (Philco Corp., Advanced Communication Systems Laboratory, Blue Bell, Pa.).

IN: INTERNATIONAL CONVENTION ON MILITARY ELECTRONICS, 8TH, WASHINGTON, D. C., SEPT. 14-16, 1964, CONFERENCE PROCEEDINGS.

Conference sponsored by the Military Electronics Group of the Institute of Electrical and Electronics Engineers.

Edited by B. J. Goldfarb.

North Hollywood, Western Periodicals Co., 1964, p. 67-72.

Contract No. AF 30(602)-2901.

Description of a coherent optical phased-array system including a discussion of other physical devices and component sensitivities required to achieve beam steering of a single laser. The phased-array design is considered in detail. The output lens system used to eliminate grating lobes in the phased-array system reportedly sets a limit to the maximum achievable scan angle at each output laser. The limitation is indicated to occur through the shifting of the beam diameter across the face of the telescope optics which degrades the element illumination function and subsequently degrades the sidelobe level due to grating lobes. For a single, temperature-compensated prism pair, the total coverage is said to be limited to

24' of arc in each plane, although prisms can reportedly be cascaded to increase the coverage angle. The maximum scanning speed of the array is indicated to be 50 kc, limited by the transit time for pressure-wave motion in the azimuth and elevation delay lines; it is believed that this response time could be improved if the delay lines were made in smaller cross section. Instantaneous bandwidth of the array is limited by the sensitivity of the beam position, which in turn depends on the serpentine effect. Total losses are indicated to be about 4 db. Phase errors arising from environmental variations (mainly temperature) may have to be compensated by use of servo phase loops, heterodyning, and phase shift control with an electro-optical device (Kerr cells, piezoelectric crystals, and the like).

D. H.

A64-26843**SPECTRAL PROPERTIES OF A SINGLE-MODE RUBY LASER - EVIDENCE OF HOMOGENEOUS BROADENING OF THE ZERO-PHONON LINES IN SOLIDS.**

C. L. Tang, H. Statz, G. A. deMars, and D. T. Wilson (Raytheon Co., Research Div., Waltham, Mass.).

Physical Review, 2nd Series, vol. 136, Oct. 5, 1964, p. A1-A8. 14 refs.

Contracts No. AF 33(657)-9173; No. AF 19(628)-3862.

Report of an investigation. Evidence is presented that zero-phonon lines in the electronic spectra of impurities in solids, which are due to Raman scattering of phonons by the impurity ions, are homogeneously broadened. A study of the stimulated-emission spectra of a ruby laser operating in the traveling wave modes yields this evidence. An optical maser is used in which all the cavity modes are travelling waves and there is no spatially nonuniform depletion of the inverted population. This results in single-mode operation. Photographs are presented showing the Fabry-Perot patterns and the output intensities of the laser. The results prove that at room temperature the R_1 line of ruby is homogeneously broadened by the two-phonon Raman process and the simultaneously oscillating modes in conventional ruby lasers are due to the spatially nonuniform, partially depleted, inverted population distribution of the Cr^{3+} ions. Transient and thermal effects are considered so as to determine what additional physical mechanisms may be of importance in the experiment.

T. V. Y.

A64-26848**MASER WITH COUPLED RESONATORS FOR THE DECIMETER RANGE.**

R. M. Martirosian and A. M. Prokhorov (Academy of Sciences, Physics Institute, Moscow, USSR).

(Priboiy i Tekhnika Eksperimenta, Jan.-Feb. 1964, p. 106-109.) Instruments and Experimental Techniques, Sept. 1964, p. 108-111. 6 refs. Translation.

Description of apparatus. The coupling of maser resonators leads to amplifiers with an increased bandpass. A relationship is presented for the product of the bandpass and the gain. A sketch of the resonator system for the amplifier is presented. Its design, which employs a two-frequency resonator, and its operation are discussed. The amplifier uses rubies with Cr^{3+} concentrations of 0.02% and 0.03%, the direction of the external magnetic field being perpendicular to the trigonal axis of the crystal. This homogeneous field is obtained by using a solenoid with a superconducting coil of pure niobium. The amplifier characteristics are presented along with photographs showing the gain curves and the curves characterizing the coupling between resonators. This amplifier is designed for application to radio astronomy, and combination with a radiometer will make it possible to increase the sensitivity of the instrument for the investigation of monochromatic radiation from galactic hydrogen.

T. V. Y.

A64-26860**LASERS FOR LENGTH MEASUREMENT.**

A. G. McNish (National Bureau of Standards, Metrology Div., Washington, D. C.).

Science, vol. 146, Oct. 9, 1964, p. 177-182. 8 refs.

Discussion of the use of lasers in metrology. The principle of lasers and their applications as measuring devices are described. A Ne-He laser with concave mirrors and Brewster-angle windows and an optical system to obtain interference fringes are diagrammed. Major fields of lasers' potential uses, such as automatic fringe counting and length standards, are considered.

V. Z.

A64-26892**SOME BASIC CONSIDERATIONS IN USING LASER LIGHT ENERGY.**

Gus Stavis (General Precision, Inc., General Precision Aerospace Group, GPL Div., Pleasantville, N. Y.).

TNB General Precision Aerospace, vol. 7, 3rd Quarter, 1964, p. 14-19. 8 refs.

Brief exposition of the essentials of signal generation, propagation, modulation, and detection in optical maser systems. The intent is to acquaint nonexperts with some of the capabilities and limitations of laser devices. Some analogies are drawn between laser elements and the more familiar elements of certain microwave systems.

W. M. R.

A64-27091**MICROWAVE SOLID-STATE MASERS.**

A. E. Siegman (Stanford University, Dept. of Electrical Engineering, Stanford, Calif.).

New York, McGraw-Hill Book Co., Inc., 1964. 583 p. \$18.50.

This book, intended for electronics engineers or graduate students and for the engineer or scientist in communications, radar, or radio astronomy, provides an introduction to all the important basic physical concepts involved in the solid-state maser and an extensive coverage of the theory and current technology in the microwave-maser field. The first part of the book explains the source of the paramagnetic energy levels used in microwave masers and includes a short refresher course in atomic-energy levels, a review of the magnetic properties of atoms in general, and a chapter on Zeeman levels in maser crystals in particular. A chapter is included which gives a detailed analysis of paramagnetic resonance, including spin-lattice relaxation mechanisms, line-broadening mechanisms, cross-relaxation phenomena, cavity masers, traveling-wave masers, noise in masers, and practical aspects of maser experimentation and application. Special features of the book are: (1) a thorough review and discussion of slow-wave circuits in general and traveling-wave-maser circuits in particular and (2) an extensive discussion of noise in masers and in general. The rationalized mks system of units is used throughout, with certain compromises in usage (magnetic fields are commonly expressed in oersteds or gauss). The appendix presents the numerical calculations of energy levels and transition-probability matrix elements for ruby carried out by the author and Chang. Optical masers have not been specifically included in the book because of considerations of length. However, since the basic principles of maser theory, maser amplification, and maser noise are independent of the frequency range involved, many of the discussions and concepts in the book are considered directly useful to anyone interested in optical masers.

D. H.

A64-27386**AN AFTERHEATER FOR USE WITH HIGH-TEMPERATURE VERTICAL CRYSTAL PULLERS.**

J. D. Ridley and B. Cockayne (Ministry of Aviation, Royal Radar Establishment, Malvern, Wores., England).

Journal of Scientific Instruments, vol. 41, Oct. 1964, p. 647.

Description of an afterheater designed to lower the strain level in single crystals of laser materials grown by pulling from the melt. The device uses three concentric alumina tubes to reduce the temperature gradients above the melt, to which the growing crystal is subjected. Simple techniques by means of which the heater can be adapted to high and low melt temperature ranges are noted.

V. P.

A64-27387**THE RUBY LASER AS A BRILLOUIN LIGHT AMPLIFIER.**

Richard G. Brewer (International Business Machines Corp., Research Laboratory, San Jose, Calif.),
Applied Physics Letters, vol. 5, Oct. 1, 1964, p. 127, 128. 8 refs.

Demonstration of the use of a ruby laser in amplifying stimulated Brillouin scattering and in facilitating Brillouin scattering measurements. The gain factor is shown to be at least 2.5 to 3 for the first-order Stokes and anti-Stokes emissions, respectively. A pronounced asymmetry of gain with wavelength is indicated, which is sufficient at other wavelengths to uncover higher Brillouin orders which are otherwise unobservable. J. R.

A64-27389 •**LASER-INDUCED DAMAGE TO TRANSPARENT DIELECTRIC MATERIALS.**

Concetto R. Giuliano (Hughes Aircraft Co., Research Laboratories, Malibu, Calif.).

Applied Physics Letters, vol. 5, Oct. 1, 1964, p. 137-139. 6 refs.

Investigation of the damage caused by the interaction of laser light with transparent dielectric materials. Among the possible mechanisms considered are: (1) direct heating effects caused by absorption of the light along the beam; (2) interaction of laser light at the material boundaries (e.g., radiation pressure or other effects that might give rise to shock waves); (3) phonons generated in the laser beam by a stimulated Raman process (i. e., the process that produces optical phonons or acoustic phonons); and (4) acoustic phonons driven at the difference frequency between two frequency components of the laser. It is concluded that the damage is caused by acoustic phonons generated in the laser beam and that these phonons have a short mean free path and are propagating in the forward direction. The phenomena are most reasonably explained by mechanism (3) as reported by Chiao, Towns, and Stoicheff. J. R.

A64-27390 •**ELECTRON-BEAM-PUMPED GaAs LASER.**

C. E. Hurwitz and R. J. Keyes (Massachusetts Institute of Technology, Lincoln Laboratory, Lexington, Mass.).

Applied Physics Letters, vol. 5, Oct. 1, 1964, p. 139-141. 13 refs.

Observation of laser action in GaAs excited by a beam of 50-keV electrons at liquid-helium temperature. The laser sample is prepared from p-type GaAs with a net acceptor density of $9.3 \times 10^{18} \text{ cm}^{-3}$ by cleaving a face perpendicular to the two parallel polished faces of a 0.21-mm-thick slice of the material. Spectra of infrared emission from electron-beam pumped GaAs at liquid-He temperature below and above the laser threshold are obtained. The intensity of the emitted radiation is found to vary approximately linearly with the beam current at low current. J. R.

A64-27391 •**LOW ABSORPTION MEASUREMENTS BY MEANS OF THE THERMAL LENS EFFECT USING AN He-Ne LASER.**

R. C. C. Leite, R. S. Moore, and J. R. Whinnery (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Applied Physics Letters, vol. 5, Oct. 1, 1964, p. 141-143. 7 refs.

Measurement of low values of absorbancies by means of a thermal-lens effect observed previously when certain liquid or solid samples were introduced into laser cavities. Values from 10^{-5} to 10^{-4} cm^{-1} are found for several organic liquids at 6328 Å, using one-centimeter cells. This method of measurement is shown to be good for materials with very low absorbancies, about 10^{-4} parts/cm. The upper limit of loss is that which prevents oscillation of the laser. Of the known sources of error in the method, that of reading the beam spot size from the curves seems dominant and causes errors of about 10% in absorbancies. J. R.

A64-27409**A RADIATIVE DETONATION MODEL FOR THE DEVELOPMENT OF A LASER-INDUCED SPARK IN AIR.**

S. A. Ramsden and P. Savic (National Research Council, Ottawa, Canada).

Nature, vol. 203, Sept. 19, 1964, p. 1217-1219. 9 refs.

Discussion of the results of a recent experiment on the spark produced in air by a focused ruby laser beam, which showed that, after breakdown, the spark develops asymmetrically, moving toward the lens within an initial velocity of $\sim 10^7 \text{ cm/sec}$. A mechanism - identical with that of a radiation-supported shock wave - is proposed for the observed effect. It is assumed that after breakdown, a shock wave propagates into undisturbed gas, and that further absorption of energy from the laser beam occurs behind the shock front traveling toward the lens, in the manner of a detonation wave. After the end of the laser pulse, the heated gas expands in the form of a blast wave. V. P.

A64-27413**LASER RADAR ECHOES FROM A STRATIFIED CLEAR ATMOSPHERE.**

Ronald T. H. Collis, Frederick G. Fernald, and Myron G. H. Ligda (Stanford Research Institute, Aerophysics Laboratory, Menlo Park, Calif.).

Nature, vol. 203, Sept. 19, 1964, p. 1274, 1275.

Discussion of observations demonstrating the ability of the laser radar to detect discontinuities in the clear atmosphere remotely by reference to back-scattering from particular matter. The observed discontinuities are associated with the thermal structure of the lower atmosphere. Oscillograms of the recorder traces are presented. V. P.

A64-27425**COUPLED-MODE LASER OSCILLATION.**

J. A. Fleck, Jr. and R. E. Kidder (California, University, Lawrence Radiation Laboratory, Livermore, Calif.).

Journal of Applied Physics, vol. 35, Oct. 1964, p. 2825-2831. 15 refs.

AEC-sponsored research.

Derivation of a set of general equations describing the time-dependent behavior of a laser. The derivation is based on a density-matrix description of a homogeneously broadened laser transition and a semiclassical treatment of the radiation field, consisting of an arbitrary number of modes. The resulting equations resemble ordinary rate and energy-conservation equations but contain additional interference terms which, in general, couple all of the modes. The strength of this coupling depends on the inhomogeneity of the population inversion, as well as on the mode frequencies. The energy-conservation equations imply that absorption and stimulated emission in such a system can apply, strictly speaking, only collectively to the system of modes as a whole. In addition, the threshold inversion is affected by mode coupling. Stability analysis carried out in the two-mode case indicates that a spatial inhomogeneity in the pumping rate is required for undamped oscillations. It is also concluded that coupling of off-axis modes is more likely to lead to undamped spiking than coupling of axial modes. (Author) W. M. R.

A64-27428**SMALL-SIGNAL ANALYSIS OF INTERNAL (COUPLING-TYPE) MODULATION OF LASERS.**

M. DiDomenico, Jr. (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Journal of Applied Physics, vol. 35, Oct. 1964, p. 2870-2876. 17 refs.

Analysis of the internal modulation of lasers by cavity loss variation in terms of the normal modes of the system. Time-dependent perturbation theory is used to describe the results of resistive mode coupling when the losses are modulated with small signals. For the single-mode oscillator, an expression is obtained for the amplitude distortion in the modulation index of the light produced by a coupling-type internal modulator when the losses are modulated at a frequency commensurate with the separation between longitudinal modes of the laser cavity. Low distortion is obtained when the modulating frequency is noncommensurate with the longitudinal-mode frequency separation. The internal coupling-type modulator in its present form can provide small amounts of modulation over bandwidths limited to the separation between adjacent

interferometer cavity normal modes. For a multimode oscillator, modulation of the internal losses at a frequency equal to the separation between adjacent longitudinal modes produces a pulse-modulated output wave. The average intensity is unchanged, and the peak intensity is increased over the intensity of the unmodulated laser by a factor equal to the number of oscillating modes.

(Author) W. M. R.

A64-27433

STUDIES OF A HIGH-GAIN PULSED ^{87}Rb MICROWAVE MASER. P. Davidovits and N. Knable (Columbia University, Radiation Laboratory, New York, N. Y.). Journal of Applied Physics, vol. 35, Oct. 1964, p. 3042. 5 refs. Army-USAF-Navy-supported research.

Experimental determination of the effects of optical pumping and of buffer gases on maser gain. Transient gain greater than unity has been attained in the period following the removal of the pumping light. The rubidium was contained in a single-port, vacuum-tight, microwave cavity tuned to the Rb-87 hyperfine transition frequency, 6835 Mc. The cavity was constructed for the TE_{011} mode and was made tunable by a flexible membrane at one end. Pumping light was admitted through the other end, which was terminated by a perforated end plate and a glass-to-stainless steel seal. Maser gain as a function of buffer gas pressure was measured for nitrogen, neon, helium, argon, and hydrogen buffer gases. The results were obtained at the peak output occurring after the removal of the pumping light and with the cavity temperature at 52°C . Where sufficient data were taken, a maximum was observed in the plot of gain vs pressure. Experiments with various gas mixtures indicate that the higher gain associated with nitrogen (0.32 at 11 torr) is the result of its superior quenching properties.

W. M. R.

A64-27438

BLUE GAS LASER USING Hg^{2+} .

H. J. Gerritsen and P. V. Goedertier (Radio Corporation of America, RCA Laboratories, Princeton, N. J.). Journal of Applied Physics, vol. 35, Oct. 1964, p. 3060, 3061. 5 refs.

Confirmation that gaseous laser operation is not limited to neutral atoms, but can extend at least as far as doubly ionized atoms. The laser tube was of quartz, 120 cm long, and of 6-mm ID with quartz Brewster windows. A molybdenum anode and mercury pool cathode were placed in sidearms. Along with the room-temperature mercury vapor pressure of 10^{-3} torr, the tube was filled with an original pressure of 0.5 torr of helium. External confocal mirrors were used for the optical cavity. Two types of excitations were used, condenser discharge and delay-line discharge. With the first method, using dielectric coated mirrors, red and green laser operation was obtained with simultaneous oscillation at 6149.5 and 5677.5 Å. When blue reflecting mirrors were used in conjunction with the delay-line discharge, a blue laser of power output comparable to the green resulted. Spectrograms were taken, and the blue transition was determined as 4797 ± 1 Å. In the literature, the only mercury transition reported in that region is a composite line centered at 4797.01 Å and established as due to a transition from the $5d^8 6s^2$ ($J = 4$) level at 126468.3 cm^{-1} to the $5d^9 6p_{1/2}$ ($J = 3$) level at 105627.8 cm^{-1} in Hg^{III} .

W. M. R.

A64-27441

2s-2p AND 3p-2s TRANSITIONS OF NEON IN A LASER TEN METERS LONG.

R. N. Zitter (Bell Telephone Laboratories, Inc., Murray Hill, N. J.). Journal of Applied Physics, vol. 35, Oct. 1964, p. 3070, 3071. 10 refs.

Observation of oscillation on 22 transitions in the 2s-2p group (Paschen notation) and 11 transitions in the 3p-2s group of neon; 7 transitions in each group have not been reported previously. The results were obtained in a laser with a total plasma length of 9.8 m and a diameter of 1 cm. Wavelength measurements were made with a Bausch and Lomb grating monochromator (500-mm focal length) equipped with a special vernier dial and a lead sulfide detector. Lines of equal strength spaced 4 Å apart could just be resolved, and measurements on known lines were reproducible and accurate to better than ± 2 Å.

W. M. R.

A64-27443

TIME-DEPENDENT VARIATION OF THE INTENSITY AND ENERGY OF THE STIMULATED EMISSION OF A RUBY LASER WITH SPHERICAL MIRRORS [IZMENENIE VO VREMENI INTENSIVNOSTI I ENERGIJA VYNUZHDENNOGO IZLUCHENIYA RUBINOVOGO LAZERA SO SFERICHESKIMI ZERKALAMI].

A. K. Sokolov and T. N. Zubarev. Fizika Tverdogo Tela, vol. 6, Sept. 1964, p. 2590-2598. In Russian.

Experimental investigation, showing that, in a ruby laser with spherical mirrors, under certain conditions, the stimulated emission in its initial phase represents regular damping oscillations near the equilibrium point. The relationship between the intensity of the stimulated emission and time is determined. In addition, a formula is derived for calculating the energy of the stimulated emission.

J. R.

A64-27445

SEMICONDUCTOR LASERS [POLUPROVODNIKOVYE KVANTOVYE GENERATORY].

N. G. Basov.

(Akademiia Nauk SSSR, Obshchie Sobranie, Moscow, USSR, June 22, 1964.)

Akademiia Nauk SSSR, Vestnik, vol. 34, Sept. 1964, p. 19-33. In Russian.

Survey of the principles of operation of semiconductor lasers, in terms of p-n junctions and donor and acceptor levels. Some representative semiconductors and their respective wavelengths are tabulated. Examined are the design and performance characteristics of: (1) a generator in which excitation is produced by an electron beam; (2) a generator employing a CdS crystal, including an illustration of the narrowing of the CdS green line as a function of electron-beam intensity; and (3) a generator using a p-n junction laser. The formation of coherent light from the radiation of individual p-n junction lasers is examined.

V. P.

A64-27492

CONTACT PRINTING WITH COHERENT LIGHT.

Helmut Heckscher and Brian J. Thompson (Technical Operations, Inc., Burlington, Mass.).

(Society of Photographic Scientists and Engineers, International Conference, New York, N. Y., Apr. 27-May 1, 1964.)

Photographic Science and Engineering, vol. 8, Sept.-Oct. 1964, p. 260-265.

Contract No. AF 30(602)-3139.

Investigation of the use of lasers for contact printing. It is stated that the high degree of collimation and the high illuminance that can be simultaneously obtained from the output of a laser make it attractive as a light source in contact printers. However, special problems exist in such a system, mainly arising from the high degree of both spatial and time coherence of the laser output. These properties cause deleterious interference and diffraction effects in many printing systems. Experiments are described using a He-Ne gas laser as a light source associated with standard printing frames and continuous drum printers. The troublesome effects are illustrated, and a method of eliminating them is discussed.

M. M.

A64-27690

SPECTROSCOPIC PROPERTIES OF ACTIVATED LASER CRYSTALS. II.

P. Görlich, H. Karras, G. Köstitz, and R. Lehmann.

Physica Status Solidi, vol. 6, Aug. 1, 1964, p. 277-318. 24 refs.

Survey of data on the spectroscopic properties of activated laser crystals. A table lists the values of half width, quantum efficiency, and lifetime of $\text{SrCl}_2:\text{Sm}^{2+}$, in comparison with $\text{SrF}_2:\text{Sm}^{2+}$, which differ only slightly at 4.2°K . It is stated that, in addition to the crystalline substances described, various glasses used as host substances for rare-earth ions proved to be suitable for laser applications. Absence of crystal structure generally manifests itself in a broadening of the emission lines and comparatively higher threshold values. The advantages of the glass result from a simpler production technology, a better optical quality, and higher possible activator concentrations, as well as the possibility of optimizing the properties by varying both the composition and the proportions. It is noted that the combination of laser technology and fibre-glass technology will offer great possibilities for the future.

M. M.

A64-27704

LIGHT MODULATION AND ITS APPLICATIONS TO TELECOMMUNICATIONS [LA MODULATION DE LUMIERE ET SES APPLICATIONS AUX TELECOMMUNICATIONS].

Gérard Marie (Laboratoires d'Electronique et de Physique Appliquée, Paris, France).

Société des Ingénieurs Civils de France, Mémoires, vol. 117, Oct. 1964, p. 19-29; Discussion, p. 30. In French.

Consideration of the importance of light modulation applied to telecommunications. The principal physical phenomena that can be utilized in order to bring about light modulation are indicated, and the advantages presented by the linear electro-optical effect, or Pockels effect, which appears in some classes of crystals, stressed. A description of modulators for the transmission of one or several television channels, and of the performance to be expected by such systems combined with a HeNe gas laser is provided.

M. M.

A64-27747

DIFFRACTION LOSS AND BEAM SIZE IN LASERS WITH SPHERICAL MIRRORS.

M. J. Taylor, G. R. Hanes, and K. M. Baird (National Research Council, Applied Physics Div., Ottawa, Canada).

Optical Society of America, Journal, vol. 54, Nov. 1964, p. 1310-1314. 9 refs.

Report of the experimental determination of the diffraction loss and beam size of the TEM₀₀ mode in gas lasers. The apparatus, procedure, and results are described in some detail, and the spot size was found as a function not only of diffraction loss in the cavity but also of mirror radii of curvature. The results are considered to be in agreement with theoretically predicted values to within the experimental error, except that the increase in beam size with reduction of mirror size was found to be less than predicted.

D. H.

A64-27928

THE EXACT TREATMENT OF A MASER MODEL [EXAKTE BEHANDLUNG EINES MASER-MODELLS].

E. Abate and H. Haken (Stuttgart, Technische Hochschule, Institut für theoretische und angewandte Physik, Stuttgart, West Germany). *Zeitschrift für Naturforschung*, vol. 19a, July-Aug. 1964, p. 857-861. 6 refs. In German.

Study of the interaction of a single cavity mode with a system of atoms, all with the same transition frequency which is assumed to be equal to the frequency of the mode. Both the mode and the atoms are assumed to have infinite lifetimes when not coupled together. The time dependence of the number of photons is determined by a computer, taking into account up to 80 atoms. The photon number oscillates as a function of time. The results are compared with those of approximate methods used by Serber and Townes and Frish and Haken. In addition, a new semiclassical treatment of the equations of motion is given, which is capable of showing the oscillations of the photon number.

J. R.

A64-27933

SOLUTIONS OF ORGANIC COLORANTS USED AS OPTICAL SWITCHES FOR GENERATING GIANT LASER PULSES [LÖSUNGEN ORGANISCHER FARBSTOFFE ALS OPTISCHE SCHALTER ZUR ERZEUGUNG VON LASER-RIESENIMPULSEN].

Fritz P. Schiffer and Werner Schmidt (Marburg an der Lahn, Universität, Physikalisch-Chemisches Institut, Marburg an der Lahn, West Germany).

Zeitschrift für Naturforschung, vol. 19a, July-Aug. 1964, p. 1019, 1020. In German.

Brief description of a method for generating giant laser pulses by using the solution of an organic colorant as an optical switch. It is noted that the method can also be used to measure the absorption spectrum of organic molecules which are in the first excited singlet state.

J. R.

A64-28026

THE THEORY OF AN OPTICAL GENERATOR OPERATING IN STATIONARY CONDITIONS [K TEORII OPTICHESKOGO GENERATORA, RABOTAIUSHCHEGO V STATSIONARNOM REZHIME].

A. L. Mikaelian, M. L. Ter-Mikaelian, and Iu. G. Turkov. *Radiotekhnika i Elektronika*, vol. 9, Aug. 1964, p. 1357-1367. 11 refs. In Russian.

Derivation of equations describing the processes in optical generators operating in continuous regimes. General expressions are derived for the output power, threshold pumping level, and distribution of the inverse population density and energy of induced radiation along the length of the resonator. The relationship is established between the output power and parameters of the active medium, resonator, and pumping power. The amplification regime is also considered.

J. R.

A64-28037

EXPERIMENTAL INVESTIGATION OF THE ENERGY CHARACTERISTICS OF A RUBY LASER [EKSPERIMENTAL'NOE ISSLEDOVANIE ENERGETICHESKIKH KHARAKTERISTIK RUBINOVOGO OPTICHESKOGO KVANTOVOGO GENERATORA].

A. L. Mikaelian, V. M. Gardash'ian, N. A. Sakharova, and Iu. G. Turkov.

Radiotekhnika i Elektronika, vol. 9, Aug. 1964, p. 1542-1545. In Russian.

Description of the results of an experimental investigation of the basic characteristics of ruby lasers, with particular emphasis on such laser parameters as threshold pumping energy and emission energy. The relationships between the emission energy and threshold pumping level, the threshold pumping energy and transmission coefficient, and between these parameters and the diameter of the ruby rod are established.

J. R.

A64-28082

LASERS.

Arthur W. Eichmann (Hughes Aircraft Co., Aerospace Group, Research and Development Div., Culver City, Calif.). *Space/Aeronautics*, vol. 42, Sept. 1964, p. 78-80.

Discussion of the state of the art. The frequency spectrum at the submillimeter wavelengths has been extended out to 86.9 μ by means of lasing action in noble gases operating at excitation energies near the ionization levels. Ruby lasers have proved exceptionally useful in high-power applications because of their superior heat-transfer properties and greater resistance to internal thermal strains. Garnet lasers are recent discoveries which make use of neodymium-doped yttrium-aluminum, yttrium-gallium, and gadolinium-gallium. A passive Q-switch, in the form of a small cell of a solution of one of the metal-organic compounds known as the phthalocyanines, has been announced. Methods of combining the output of several lasers in a phased array are being studied. Raman laser action now has been reported for more than 30 different compounds. Most of these are benzene-ring compounds, but Raman action has also been achieved in carbon tetrachloride. Some of the problems are: low and limited efficiency, cooling power requirements, damage to laser crystal in high-peak-power use, work required on modulation and deflection of beams, as well as optical heterodyning.

T. V. Y.

A64-28098

ELECTROMAGNETIC MEASUREMENT.

Harvey W. Lance (National Bureau of Standards, Radio Standards Div., Boulder, Colo.).

Space/Aeronautics, vol. 42, Sept. 1964, p. 199-202. 6 refs.

Discussion of methods used in setting frequency standards and measuring frequencies in the entire spectrum. Frequency standards are broadcast by the US Navy in the 18- to 24-ke range with a drift rate of one part in 10^{10} and by the NBS on 60 and 20 kc. The US frequency standard is a cesium-beam-type known as NBS II. The newest kind of high precision standard is the atomic hydrogen maser. Low-frequency measurements have been aided by the development of a new calculable capacitor that permits more accurate capacitance and ohmic determinations. A recent development in HF measurements has been the increased attention given to

Fredholm's equations. The method of least squares applied with the use of analog techniques permits successful solving of a large variety of integral equations including those not satisfying the conditions of convergence of iteration methods. V. Z.

A64-28256**CALCULATION OF NONSTATIONARY PROCESSES IN LASERS [K RASCHETU NESTATIONARNYKH PROTSESSOV V LAZERAKH].**

A. L. Mikaelian, M. L. Ter-Mikaelian, and Iu. G. Turkov.

Radiotekhnika i Elektronika, vol. 9, Oct. 1964, p. 1788-1799.

8 refs. In Russian.

Discussion of the radiation-pulse origin in optical amplifiers. The time constant of an amplifier is determined. The occurrence of losses in an active medium is shown to limit the generation of high-level energies by lengthening the device. The maximum possible radiation energy density is calculated. The effect of internal losses on the radiation power is examined in a generator with instantaneous figure-of-merit switch-on. V. Z.

A64-28289**OPTICAL TECHNIQUES FOR ELECTRONIC ENGINEERS.**

Ronald M. Benrey (Massachusetts Institute of Technology, Cambridge, Mass.).

IN: OPTOELECTRONIC DEVICES AND CIRCUITS.

Edited by Samuel Weber.

New York, McGraw-Hill Book Co., 1964, p. 2-8.

Discussion of the combination of physical and mathematical sciences pertaining to the nature, properties, generation, and control of electromagnetic radiation, and including the phenomenon of vision. Developments in IR, millimeter waves, and optical masers require that electronic engineers cross the arbitrary boundaries between electronics and optics. Topics discussed are: classical optics, optical quality materials, diffraction-limited optics, interference, the optical maser, and coherence. Illustrations include: components for reflecting optical systems, a chart of the useful optical spectrum, diagrammatical explanation of thin-film optical coatings, and a tabulation of optical maser wavelengths for devices operating at the time of publication. D. H.

A64-28291**PRINCIPLES OF INJECTION LASERS.**

Marshall I. Nathan and Gerald Burns (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

IN: OPTOELECTRONIC DEVICES AND CIRCUITS.

Edited by Samuel Weber.

New York, McGraw-Hill Book Co., 1964, p. 24-28. 28 refs.

Discussion of the properties of a laser that does not require optical pumping and that can convert dc power directly into coherent light. Such semiconductor junction lasers (or injection lasers) are said to be more efficient and compact than conventional lasers and to offer attractive possibilities for internal modulation. The operation of both types of laser are contrasted, and the properties of a particular injection laser - the GaAs laser - are discussed. The quantum efficiency, spectrum, and threshold of GaAs lasers are discussed, and other lasers, such as Ga(As-P), InAs, InP, (Ga-In)As and InSb lasers, are described. The injection laser is said to be a very efficient source of light and to be very easy to fabricate. It reportedly can be modulated at high frequencies, and, although it cannot compete with other solid-state lasers in peak pulsed power, it surpasses any other existing laser in CW output power. D. H.

A64-28292**HOW RARE EARTH CHELATE LASERS WORK.**

Max Metlay (General Electric Co., Advanced Technology Laboratories, Schenectady, N. Y.).

IN: OPTOELECTRONIC DEVICES AND CIRCUITS.

Edited by Samuel Weber.

New York, McGraw-Hill Book Co., 1964, p. 29, 30. 9 refs.

Discussion of the characteristics, energy levels, measurements, and possibilities of rare-earth chelate lasers using, for example, europium trisbenzoylacetate. Advantages of the rare-earth chelates for laser applications reportedly derive from their solubility in a variety of organic solvents and in various plastics. Plastic-based lasers are said to allow special shapes for special purposes; liquids are useful for high power lasers because of their ability to dispose of excess heat rapidly. In addition, it is believed possible to chemically tune such a laser by making small variations in the structure of the chelates, thereby causing slight differences in lasing wavelength. D. H.

A64-28293**INJECTION-LASER SYSTEMS FOR COMMUNICATIONS AND TRACKING.**

C. M. Johnson (International Business Machines Corp., Federal Systems Div., Bethesda, Md.).

IN: OPTOELECTRONIC DEVICES AND CIRCUITS.

Edited by Samuel Weber.

New York, McGraw-Hill Book Co., 1964, p. 46-51. 16 refs.

Presentation of derivations of expressions for operating parameters for injection-laser communication and tracking systems. Expressions are given for: (1) transmitter power required for a communication link where the receiver is quantum-noise limited and the antennas are diffraction-limited, (2) minimum detectable signal of an optical receiver of the envelope type, (3) average transmitter power required for an optical communications system, and (4) the efficiency of an injection laser. Additional topics covered are: an experimental communications system with PFM to transmit a 4-kc voice channel, a proposal for a satellite link, readout, astronaut link, laser tracking, scanning antennas, and resolution. A brief supplementary account is given of the present state of the art of injection lasers. D. H.

A64-28294**OPTICAL RANGING SYSTEM USES LASER TRANSMITTER.**

M. L. Stitch, E. J. Woodbury, and J. H. Morse (Hughes Aircraft Co., Culver City, Calif.).

IN: OPTOELECTRONIC DEVICES AND CIRCUITS.

Edited by Samuel Weber.

New York, McGraw-Hill Book Co., 1964, p. 60-62.

Description of a coherent light detection and ranging (Colidar) system. The system reportedly transmits with an angular beamwidth of approximately 1 minute of arc and, compared to pulsed-arc light radar, is said to have the advantages of greater brightness, monochromatic emission (permitting the use of optical band-pass filters in the receiving circuit and thereby permitting long-distance ranging in daylight), and freedom from arc wandering or walking. Illustrations include a block diagram of the transmitter and receiver systems and wiring diagrams of the receiver preamplifier, the trigger preamplifier, and the flash-tube power supply. D. H.

A64-28295**PULSE POWER SUPPLY DESIGN FOR LASER PUMPING.**

S. J. Grabowski (General Electric Co., Defense Electronics Div., Heavy Military Electronics Dept., Syracuse, N. Y.).

IN: OPTOELECTRONIC DEVICES AND CIRCUITS.

Edited by Samuel Weber.

New York, McGraw-Hill Book Co., 1964, p. 68-70.

Presentation of a circuit design requiring a minimum of equipment and combining constant-current capacitor charging and output-voltage limiting. Wiring diagrams are presented and discussed for a constant-current network, a load-control circuit with voltage-limiting, and a pulse-forming modulator that operates the laser-pumping flash lamp. D. H.

A64-28297**THE VERSATILE POINT-CONTACT DIODE - HOW IT DETECTS AND AMPLIFIES LASER LIGHT.**

S. Saito, K. Kurokawa, Y. Fujii, T. Kimura, and Y. Uno (Tokyo, University, Institute of Industrial Science, Tokyo, Japan).
IN: OPTOELECTRONIC DEVICES AND CIRCUITS.
Edited by Samuel Weber.
New York, McGraw-Hill Book Co., 1964, p. 80-83.

Report of a study of several methods of demodulating laser signals into microwave. It has been found that the semiconductor (point-contact) diode has a high quantum efficiency. In addition, the diode can be used in the IR region of the spectrum and is said to allow parametric amplification of the demodulated signal. Experiments show that parametric diodes can demodulate and amplify the signal from a ruby laser. Two kinds of silver-bonded, point-contact parametric diodes were tested; a germanium GSB1B diode and a silicon test specimen.

D. H.

A64-28305

STATISTICS OF LASER AND THERMAL RADIATION.

Henri Hodara (National Engineering Science Co., Pasadena, Calif.).
IN: WESTERN ELECTRONIC SHOW AND CONVENTION, LOS ANGELES, CALIF., AUGUST 25-28, 1964, TECHNICAL PAPERS. VOLUME 8. PART III - ELECTRON DEVICES, COMPONENT PARTS.

North Hollywood, Western Periodicals Co., 1964, p. 17.4-1, 17.4-2. 6 refs.

Derivation of the statistics of multimode laser signals and their comparison to those of an incoherent radiation. It is found that the statistics are greatly different if the laser operates in a single mode but become similar as the mode purity is degraded.

M. M.

A64-28361

MASERS AND LASERS.

M. Brotherton (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

New York, McGraw-Hill Book Co., Inc., 1964. 207 p. \$8.50.

An historical account is presented of the origin and evolution of the maser and the laser. This book was reportedly conceived for those who would like to have an explanation of lasers and masers which, while factual and authentic, stays away from formulas and formulations beyond their grasp. The first portion of the book provides background information. Topics covered in this portion are: electricity, magnetism, and waves; electrons and electron tubes, electromagnetic radiation and spectroscopy; the atom and its electron world; and photons. The second part of the book introduces the concept of stimulated emission of radiation and discusses various types of masers and lasers. Subjects in this part are: atomic-energy ladders, the first maser, traveling-wave ruby masers, ruby lasers and helium-neon lasers, and semiconductor-junction lasers. Additional topics included are: waves and wave motions, electromagnetic-wave generators, maser uses and applications, laser uses and applications, simultaneous multivoice transmission, the battle of the bandwidth, and a capsule history of the maser and laser.

D. H.

A64-28362HOT-PRESSED POLYCRYSTALLINE $\text{CaF}_2:\text{Dy}^{2+}$ LASER.

S. E. Hatch, W. F. Parsons, and R. J. Weagley (Eastman Kodak Co., A and OD Research Dept., Rochester, N. Y.).

Applied Physics Letters, vol. 5, Oct. 15, 1964, p. 153, 154. 6 refs.

An evaluation of the feasibility of hot-pressed polycrystalline laser materials. The starting powder is prepared by vacuum melting the desired proportion of CaF_2 and DyF_3 and then pulverizing the solidified material to $\sim 150 \mu$. Material of essentially theoretical density is made by compacting the powder by simultaneous application of heat and pressure in vacuum hot-pressing equipment. Rods were prepared from fifteen different pressings. As a means of comparing threshold, three single-crystal $\text{CaF}_2:\text{Dy}^{2+}$ rods of the same size, doped with 0.05-mole% Dy^{3+} and then irradiatively reduced, were purchased. The threshold for pulsed operation was

observed for all of the rods immersed in liquid nitrogen and for several immersed in liquid helium. The mean threshold for the hot-pressed rods at liquid-nitrogen temperature was 24.6 J with an average deviation of 2 J, while that of the single-crystal rods was 25.4 J with an average deviation of 4 J. A comparison of the properties of both forms is said to show that the polycrystalline one approaches the single crystal.

T. V. Y.

A64-28363RELAXATION RATES OF THE Ar^+ LASER LEVELS.

W. R. Bennett, Jr., P. J. Kindlmann, G. N. Mercer, and J. Sunderland (Yale University, Sloane Physics Laboratory, New Haven, Conn.).

Applied Physics Letters, vol. 5, Oct. 15, 1964, p. 158-160. 14 refs.

Measurement of the radiative and collision-induced relaxation rates showing that: (1) the radiative lifetimes of the Ar^+ levels concerned range from 7 to 10 nsecs, (2) the destructive collision cross sections are too small to alter these lifetimes significantly over the optimum pressures for laser oscillation, and (3) the direct Ar^+ excitation cross sections are comparable with typical values for the neutral-argon levels. Direct excitation with pulses of threshold energy electrons was used, and the decay rates of isolated transitions were studied with a 500-channel, delayed-coincidence analyzer having a time calibration of 2 nsecs per channel. The data are summarized in a table where limiting values of the total velocity-averaged, destructive cross sections have been evaluated for a gas temperature of 380°C. Over the pressure range 0.01 to 2 torr, pressure variation in the decay rate was unobservable in many cases and less than 10% in the others. It is assumed that the strong pressure dependence encountered in the laser performance must have its origin either in effects involving the upper- and lower-state excitation processes or in relaxation mechanisms in lower levels of the lasing ions.

T. V. Y.

A64-28565

MODULATION OF A HE-NE LASER BY MEANS OF A TELEVISION SIGNAL [MODULATION EINES HE-NE-LASERS MIT EINEM FERNSEHSIGNAL].

O. Hintringer and G. Schiffner (Wien, Technische Hochschule, Institut für Hochfrequenztechnik, Vienna, Austria).

Nachrichtentechnische Zeitschrift, vol. 10, Oct. 1964, p. 501, 502. 8 refs. In German.

Research supported by the Österreichische Bundesregierung.

Description of an experimental device that uses a video signal to modulate a laser beam of a wavelength of 6328 Å. The output of the laser is modulated by a Pockels-effect KDP crystal, located within the cavity resonator of the laser. The video signal premodulates a carrier (55.25 Mc) which is then applied to the modulating crystal. The video signal is demodulated by a Si photodiode. Test results obtained with the device are presented and discussed.

V. P.

A64-28603

EFFECT OF SPONTANEOUS EMISSION ON THE TRANSIENT RESPONSE OF LASERS [EINFLUSS DER SPONTANEN EMISSION AUF DAS EINSCHWINGVERHALTEN VON LASERN].

Dieter Röss (Siemens und Halske AG, Zentral-Laboratorium, Munich, West Germany).

Zeitschrift für Naturforschung, vol. 19a, Oct. 1964, p. 1169-1177. 24 refs. In German.

Derivation of approximate equations describing the transient response of multilevel lasers, on the basis of a modification of the balance equations. Numerical solutions of the derived equations are found to correlate well with test results obtained with multilevel lasers. The results indicate that, at a low pumping rate, the effect of spontaneous emission upon the laser transient response may not be neglected even for single-level lasers.

V. P.

A64-28610

SUBSYSTEMS OF A RUBY LASER [ELEMENTY USTANOVKI RUBINOVOGO KVANTOVOGO GENERATORA].

S. M. Mamedzade.

Akademiia Nauk Azerbaidzhanskoi SSR, Izvestiia, Seriia Fiziko-Tekhnicheskikh i Matematicheskikh Nauk, no. 3, 1964, p. 135-141. 5 refs. In Russian.

Detailed discussion of the elements of a solid-state laser, and the principles of the generation of coherent light. Covered are:

- (1) the population inversion of the energy levels by optical pumping;
- (2) the electrical subsystem for optical excitation, including the high-voltage generator, the capacitor bank, the optical pumping system, and the ionization system; and (3) the cavity resonator.

V. P.

A64-28615

GENERATION OF GIANT PULSES FROM A NEODYMIUM LASER BY A REVERSIBLY BLEACHABLE ABSORBER.

B. H. Soffer and R. H. Hoskins (Korad Corp., Santa Monica, Calif.).

Nature, vol. 204, Oct. 17, 1964, p. 276.

Reported observation of giant pulses at 1.06μ from a neodymium glass laser using the polymethine dye 3,3'-diethyl-9,11;15,17-dineopentylene-thia-pentacarbocyanine iodide as the bleachable absorber. A 0.25×2 in. rod of neodymium-doped glass with external dielectric mirrors was used. The threshold for ordinary laser action was approximately 850 joules. A solution of the dye in a rectangular cell was placed in the cavity, and the optical density of the cell was increased by steps from 0 to 0.3 in a series of experiments. The pulses were measured with a fast-rise S-1 planar photodiode calibrated calorimetrically and were observed on an oscilloscope having a 4-nanosec rise time. The ordinary laser pulses (optical density zero) had a minimum width of about 1μ sec and a maximum amplitude of 12 kw with an input pumping energy of 1800 joules. The total energy output of the giant (1-Mw peak power) pulses obtained was typically 5% of the total ordinary laser output. No deterioration of the dye due to exposure to the laser light was noted in approximately 100 flashes.

W. M. R.

1965

IAA ENTRIES

A65-10053

THE THEORY OF LASER RADIATION.

M. L. Ter-Mikaelian and A. L. Mikaelian (Erevanski Gosudarstvennyi Universitet, Yerevan, Armenian SSR).

(Akademiia Nauk SSSR, Doklady, vol. 155, Apr. 1, 1964, p. 1298-1301.)

Soviet Physics - Doklady, vol. 9, Oct. 1964, p. 305-307. 9 refs. Translation.

Formulation of approximate equations describing the processes by which light is generated in lasers. The intensity of light emitted by a laser is determined in terms of the change in the flux of quanta, the over-occupancy of energy levels, cross section, and pumping rate. The intensity and inverse effective length are found for the steady-state case, and the times characterizing pulsed radiation are determined for the transient case, averaged over the length of the generating element.

D. H.

A65-10076 #

POSSIBILITY OF THE UTILIZATION OF COMBINED RESONANCE TO PRODUCE A MASER EFFECT [O VOZMOZHNOСТИ ISPOL'ZOVANIIA KOMBINIROVANNOGO REZONANSA DLIA POLUCHENIIA MAZERNOGO EFFEKTA].

E. I. Rashba (Akademiia Nauk Ukrainsskoi SSR, Institut Poluprovodnikov, Kiev, Ukrainian SSR).

Fizika Tverdogo Tela, vol. 6, Oct. 1964, p. 3178, 3179. 15 refs. In Russian.

Discussion of the principle of a semiconductor pulse maser based on the theory of existence of electro-dipole transitions with spin orientation shifts. A quantum-limited semiconductor in which all zonal electrons concentrate in the lowest Landau orbit in the absence of current, with spins in the $0,-$ state, is investigated.

V. Z.

A65-10184

QUANTUM-MECHANICAL EFFECTS IN STIMULATED OPTICAL EMISSION. II.

Roscoe C. Williams (Radio Corporation of America, RCA Laboratories, Princeton, N.J.).

Physical Review, 2nd Series, vol. 136, Nov. 2, 1964, p. A631-A636. 14 refs.

Demonstration that multiple-quantum transitions exist in optically pumped lasers, along with splitting of the laser line due to the modulation of the wave function at an angular frequency determined by the rate of pumping, for a certain class of incoherent broadband sources pumping large pump bands in crystals. It is stated that the source consists of a large number of stationary elements emitting wave fields continuously at various arbitrary frequencies and arbitrary phases. The distribution of frequencies and phases among the various elements is random. The pump band belongs to the class found in laser crystals of the ionic type. The analysis shows that such sources pumping such bands act like narrow-line sources pumping narrow lines. The effective linewidth is said to be directly related to the pump rate. (Author) M. M.

A65-10219

THE COMPLEX MAGNETIC SUSCEPTIBILITY OF MASER RUBIES AT MICROWAVE FREQUENCIES.

H. Kiemle and H. Rothe (Karlsruhe, Technische Hochschule, Institut für Hochfrequenztechnik und Hochfrequenzphysik, Karlsruhe, West Germany).

IEEE, Proceedings, vol. 52, Oct. 1964, p. 1243.

Research supported by the German Research Association.

Discussion of the input admittance of a cavity filled with paramagnetic material to determine the resonant susceptibility associated with the microwave transition of the paramagnetic material. Transitions can be either normal, absorptive ones or inverted, emissive maser transitions. A rectangular TE_{101} cavity was used that was almost completely filled with ruby and a ceramic material of nearly the same dielectric constant so that the filling factor was amenable to computation. For paramagnetic resonance, a dc magnetic field of 2.75×10^3 oersteds perpendicular to the crystal c axis was required. A slotted line was used to measure two complex input admittances of the cavity: that with the paramagnetic resonance detuned and that at resonance. Their difference permits a determination of the complex susceptibility. A technique, attributed to Ginzton, of interchanging the roles of generator and receiver in the usual slotted-line scheme is said to avoid saturation of the signal transition. Results are expressed graphically.

D. H.

A65-10220

DIRECT OBSERVATION OF DIFFERENCE FREQUENCY SIGNAL IN A TRAVELING-WAVE MASER.

F. Bosch, H. Rothe, and E. O. Schulz-Dubois (Karlsruhe, Technische Hochschule, Institut für Hochfrequenztechnik und Hochfrequenzphysik, Karlsruhe, West Germany).

IEEE, Proceedings, vol. 52, Oct. 1964, p. 1243-1245.

Research supported by the Deutsche Forschungsgemeinschaft.

Presentation of performance data for a three-level, solid-state, traveling-wave maser in an experiment producing a signal of difference frequency $f_2 - f_1$. The detection device (a drawing of which is included) is said to produce a 30-Mc voltage at the pick-up coil. This is determined from a consideration of the quasi-static flux distribution at 30 Mc. The signal is amplified by a 30-Mc receiver of

1.5-db noise figure. It is indicated that the numerical agreement between the experimental and the theoretical curves may be taken as further evidence for the theory of spin dynamics and multiple quantum transitions in a maser. The work is considered to be a straightforward extension of the theory taking into account the experimental geometry and polarization of the difference frequency magnetization. D. H.

A65-10221**LASER FREQUENCY TRANSLATION BY MEANS OF ELECTRO-OPTIC COUPLING CONTROL.**

R. Targ, G. A. Massey (Sylvania Electric Products, Inc., Sylvania Electronic Systems Div., Mountain View, Calif.), and S. E. Harris (Stanford University, Stanford, Calif.). IEEE, Proceedings, vol. 52, Oct. 1964, p. 1247, 1248. Contract No. AF 33(615)-1938.

A method of translating the output frequency of a laser oscillator by an amount which is not restricted by the atomic linewidth of the active medium. The basic idea is said to be to accomplish the frequency translation in the output coupling of the laser oscillator, such that all of the energy which leaves the laser cavity has been translated in frequency. A frequency-translating electro-optic coupling element is described which utilizes crystals in the class $42m$ - e.g., KDP. The principle of operation of the coupling element is said to be similar to that of a SSB modulator which was proposed earlier by Bührer. The Jones matrix representing the electro-optic crystal is used to obtain an expression for the signal which is coupled out of the laser oscillator. The light coupled out of the cavity by means of the modulator was analyzed with a Fabry-Perot interferometer, and it was determined that the output was an SSB suppressed carrier. It is believed that this type of modulation should prove useful in many applications because of its great efficiency relative to external modulators. D. H.

A65-10222**PROPERTIES OF COOLED, UNCOATED RUBY LASER OSCILLATORS.**

F. A. Brand, H. Jacobs, C. LoCascio (U.S. Army, Electronics Command, Electronics Research and Development Laboratory, Fort Monmouth, N. J.), G. Novick, and D. Schick (Monmouth College, West Long Branch, N. J.). IEEE, Proceedings, vol. 52, Oct. 1964, p. 1255, 1256.

Discussion of the results of further study of the oscillator characteristics of unsilvered ruby lasers at 77°K. Only the amplifier section was used in an oscillator mode and laser output was monitored at one end by a TRG ballistic thermocouple and at the other by a solar cell. Two illustrations are included: a composite oscillogram showing the laser output as a function of voltage applied to the capacitor bank and a graph of the variation in measured output energy for the range of applied voltages. It is found that: the delay time between pump initiation and the onset of laser action decreases with increasing capacitor voltage; both laser power and energy output increase with increasing pump voltage, but there is a definite saturation; random spiking is diminished as the pump voltage is increased; the duration of the laser pulse decreases as the pump voltage increases; in most instances (especially in the case of high pump voltage), the entire lasing event is over while the pump is still delivering power at essentially its maximum rate. D. H.

A65-10223**CW OPERATION OF GaAs INJECTION LASERS.**

M. F. Lamorte, R. B. Liebert, and T. Gonda (Radio Corporation of America, RCA Electronic Components and Devices, Somerville, N. J.). IEEE, Proceedings, vol. 52, Oct. 1964, p. 1257, 1258. 10 refs.

Discussion of the minimum requirements for CW operation in a GaAs laser. On the basis of a simple thermodynamic system model, lasing criteria are found which are said to be in good agreement with conditions previously reported. Data are presented in

graphical form for junction temperature vs current for a case temperature of 2.4°K and of 77°K, with quantum efficiency as a parameter. It is seen that, for case temperatures higher than 200°K, CW operation is not possible even with the 100% external quantum efficiency obtained by Burns et al. D. H.

A65-10224**OXYGEN LASER AGING CHARACTERISTICS.**

Gordon B. Jacobs (General Electric Co., Electronics Laboratory, Syracuse, N. Y.).

IEEE, Proceedings, vol. 52, Oct. 1964, p. 1259, 1260.

Research supported by the Department of Defense; Contract No. AF 30(602)-3111.

Documentation of some properties of the argon/oxygen laser - particularly the power output as a function of time. A 6-mm ID quartz laser tube, with 176 cm of useful plasma length, was filled with an argon and oxygen mixture (1.3 torr argon and 0.035 torr oxygen) and excited by 200 watts of 26-Mc RF energy. It is indicated that the two primary causes of aging in such lasers seem to be cleanup of oxygen into the quartz walls and the effects of impurities driven from the quartz walls. These effects and the effects of adding oxygen after various intervals are shown in graphical form. Greatest efficiency was achieved with two 8-in. - long, half-circle electrodes located at the 1/3 points and excited in push-pull. D. H.

A65-10225**NEAR INFRARED LASERING IN Ne-Cl₂ AND He-Cl₂.**

R. A. Paananen and F. A. Horrigan (Raytheon Co., Research Div., Waltham, Mass.).

IEEE, Proceedings, vol. 52, Oct. 1964, p. 1261, 1262. 5 refs.

Description of an observation of a chlorine lasering line at $9451 \pm 1 \text{ \AA}$. Circumstances for the generation of the line are described, and an attempt is made to assign the transitions. All possible combinations of the known terms of Cl were searched, and three pairs were found which agreed with the observed wavelength within the range of measurement error. Of these, the $9451.92\text{-}\text{\AA}$ line was disqualified because it required a change of 4 in the total angular momentum, and the $9450.85\text{-}\text{\AA}$ line was considered an unlikely candidate because of the smallness of its quadrupole matrix elements. If the $9452.06\text{-}\text{\AA}$ line can be identified with the observed line, then the actual mechanism would be excitation of s or d levels by electron impact followed by cascade via one or possibly several IR laser transitions to the $4p^2P_{3/2}^0$ level, and the question of why only the single transition is seen will be simplified. D. H.

A65-10226**SPECTRUM PROPERTIES OF PULSE MODULATED LASERS.**

S. Karp (Douglas Aircraft Co., Inc., Missile and Space Systems Div., Advance Space Technology, Santa Monica, Calif.).

IEEE, Proceedings, vol. 52, Oct. 1964, p. 1264, 1265.

Analysis of a modulated laser, using a shot-noise analogy to determine the power-density spectrum as viewed at the output of a photodetector. It is speculated that, if one relates the time variation of the Poisson statistics with the grid-voltage variation on a triode, one might make gross assumptions in regard to laser amplitude modulation in general. Expressions are given for an unmodulated laser, an ideal photodetector, the system transfer function, and the autocorrelation function. D. H.

A65-10289 #**LASER-INDUCED EMISSION OF ELECTRONS, IONS, AND NEUTRALS FROM Ti AND Ti-D SURFACES.**

T. Y. Chang and C. K. Birdsall (California, University, Electrical Engineering Dept., Electronics Research Laboratory, Berkeley, Calif.).

Applied Physics Letters, vol. 5, Nov. 1, 1964, p. 171, 172. 10 refs. Grant No. AF AFOSR 139-63/139-64.

Description of three experiments in which it was determined that: (1) the target surface temperature produced by an unfocused laser beam is highly nonuniform, (2) the large directed ion energy produced by a focused laser beam is of the order predicted by hydrodynamic blow-off theory, and (3) the fast ion pulse produced by a focused laser beam is postulated as secondary emission at the collector due to fast D_2 molecules blown off the target surface. Oscilloscope data showing laser output and ion current vs time are presented for the first experiment. Ion current vs time is given graphically for all three experiments. D. H.

A65-10290 #
ROOM-TEMPERATURE OPERATION OF A EUROPIUM CHELATE LIQUID LASER.

H. Samelson, A. Lempicki, C. Brecher, and V. Brophy (General Telephone and Electronics Laboratories, Inc., Bayside, N. Y.). *Applied Physics Letters*, vol. 5, Nov. 1, 1964, p. 173, 174. Contract No. Nonr 4134(00).

Report of observed lasing action in a 0.01-M solution of the tetrakis form of europium benzoyltrifluoroacetate in acetonitrile. When the input to a FT-524 spiral flash tube exceeds the 1700-joule threshold, emission due to spontaneous fluorescence narrows from about 34 \AA to a single sharp line at 6119 \AA , with a halfwidth of less than 0.3 \AA . Fluorescence traces are shown for 1500 and 3000-joule inputs to the flashtube, and fluorescence emission spectra of the chelate in acetonitrile and in dimethylformamide at 25°C are presented. D. H.

A65-10291 #
TEMPERATURE DEPENDENCE OF THRESHOLD CURRENT IN GaAs LASERS.

G. C. Dousmanis, H. Nelson, and D. L. Staebler (Radio Corporation of America, RCA Laboratories, Princeton, N. J.). *Applied Physics Letters*, vol. 5, Nov. 1, 1964, p. 174-176. 5 refs.

Interpretation of the variation in GaAs-laser thresholds in terms of differences in density of states vs energy curves in the impurity "tails" associated with the conduction band. Illustrations are presented and discussed showing differences between diffused GaAs laser diodes and epitaxial diodes in regard to: (1) threshold current density vs laser wavelength at 4.2 and 78°K , (2) threshold current vs temperature, and (3) calculated curves of threshold vs temperature for various values of the density of states parameter. It is indicated that, for temperatures greater than about 50°K , epitaxial GaAs lasers have lower thresholds than the diffused diodes. D. H.

A65-10304
POLARIZATION OF THE LIGHT OUTPUT FROM A RUBY OPTICAL MASER.

J. H. Brunton (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Applied Optics, vol. 3, Nov. 1964, p. 1241-1246. 7 refs.

Description of an optical method for recording the polarization of the light output from ruby masers. The method has been used to examine the degree of polarization in a 0° ruby and in rubies of other orientations. The effect of pumping energy on polarization is also described. It is found that in all the crystals examined the amount of polarized light decreases with increasing pumping energy. J. R.

A65-10306
A NEW OPTICAL LASER PUMP.

G. J. Fan, C. B. Smoyer, and J. Nuñez (International Business Machines Corp., Thomas J. Watson Research Center, Yorktown Heights, N. Y.).

Applied Optics, vol. 3, Nov. 1964, p. 1277-1279.

Description of a new efficient laser pump consisting of a tube and two axicons. The pumping system is said to be simple to fabricate and align. Its efficiency is first estimated using geometrical optics and is compared favorably with the well-known elliptical lamp. The experimental results presented are shown to be in good agreement with the theory. J. R.

A65-10462

SOVIET MASER RESEARCH.

Edited by D. V. Skobel'tsyn (Academy of Sciences, Moscow, USSR). (Translation of Molekuliarnye Generatory, 1963.) New York, Consultants Bureau Enterprises, Inc., 1964. 186 p. \$27.50.

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A THEORETICAL STUDY OF THE FREQUENCY STABILITY OF A MASER. A. N. Oraevskii, p. 1-55. 68 refs. [See A65-10463 01-16]

CHARACTERISTICS OF MASERS (THE $J = 3, K = 3$ LINE OF $N^{14}H_3$). G. M. Strakhovskii and I. V. Cheremiskin, p. 56-87. 74 refs. [See A65-10464 01-16]

THEORY OF THE HYPERFINE STRUCTURE OF THE ROTATIONAL SPECTRA OF MOLECULES. K. K. Svidzinskii, p. 88-148. 35 refs. [See A65-10465 01-24]

THE ND_3 MASER. N. G. Basov, V. S. Zuev, and K. K. Svidzinskii, p. 149-167. 27 refs. [See A65-10466 01-16]

BIBLIOGRAPHY OF PAPERS PUBLISHED BY MEMBERS OF THE OSCILLATION LABORATORY OF THE PHYSICS INSTITUTE, ACADEMY OF SCIENCES (FIAN), USSR, 1935-1961. A. A. Sakova (Academy of Sciences, Moscow, USSR), p. 168-186.

A65-10463

A THEORETICAL STUDY OF THE FREQUENCY STABILITY OF A MASER.

A. N. Oraevskii.

IN: SOVIET MASER RESEARCH.

Edited by D. V. Skobel'tsyn.

(Translation of Molekuliarnye Generatory, 1963.)

New York, Consultants Bureau Enterprises, Inc., 1964, p. 1-55. 68 refs.

Mathematical treatment of a number of problems associated with the construction of time and frequency standards based on cesium and ammonia masers. Equations are given describing the monochromatic process and its relation to the locking of the maser to an external force. The effect of a waveguide system on the oscillations is considered. Factors influencing the oscillation frequency are analyzed, along with various methods for adjusting the frequency to that of a spectral line. Possibilities for the further increase of the frequency stability of masers are explored. A number of methods are proposed for obtaining slow molecules with an average speed much smaller than the thermal velocity at room temperature. W. M. R.

A65-10464

CHARACTERISTICS OF MASERS (THE $J = 3, K = 3$ LINE OF $N^{14}H_3$).

G. M. Strakhovskii and I. V. Cheremiskin.

IN: SOVIET MASER RESEARCH.

Edited by D. V. Skobel'tsyn.

(Translation of Molekuliarnye Generatory, 1963.)

New York, Consultants Bureau Enterprises, Inc., 1964, p. 56-87. 74 refs.

Experimental investigation of the dependence of the frequency and relative power of a maser (using the 3, 3 line of $N^{14}H_3$) on the characteristic frequency of the resonator, the voltage applied to the quadrupole condenser (or to a ring-type selection system), and the ammonia pressure in the molecular beam source. Also studied was the dependence of frequency and power of a maser with two opposed beams on the ammonia pressure in the source. Analysis of the characteristics has shown that the possible relative stability of the single-beam maser is 10^{-11} over an appreciable time period. Experimentally this stability has been maintained for over 4 hr. W. M. R.

A65-10465

THEORY OF THE HYPERFINE STRUCTURE OF THE ROTATIONAL SPECTRA OF MOLECULES.

K. K. Svidzinskii.

IN: SOVIET MASER RESEARCH.

Edited by D. V. Skobel'tsyn.

(Translation of Molekuliarnye Generatory, 1963.)
New York, Consultants Bureau Enterprises, Inc., 1964, p. 88-148.
35 refs.

Investigation of the dependence of the hyperfine interaction energy on the rotational quantum numbers and nuclear spins of maser molecules. A summary of the apparatus of the theory is given, including the application of irreducible tensor operators and the Wigner 3nj symbols. An analysis is made of the symmetry properties of the molecular wave functions, and the matrix elements of various intramolecular field operators are calculated from the rotational wave functions. The theory is applied to the concrete case of calculating the hyperfine structure of the inversion transition $J = K = 6$ in ND_3 . W. M. R.

A65-10466

THE ND_3 MASER.

N. G. Basov, V. S. Zuev, and K. K. Svidzinskii.

IN: SOVIET MASER RESEARCH.

Edited by D. V. Skobel'tsyn.

(Translation of Molekuliarnye Generatory, 1963.)

New York, Consultants Bureau Enterprises, Inc., 1964, p. 149-167.
27 refs.

Investigation of the feasibility of employing heavy ammonia molecules in a maser. Such a maser has actually been constructed with a power output at 1656.18 Mc ($J = 6$, $K = 6$ line) of 10^{-11} watt. According to preliminary data, the absolute stability of the line is on the order of 10^{-9} . Calculations of the hyperfine inversion spectrum of ND_3 are presented along with the results of studies of the working model. W. M. R.

A65-10484

TIME-RESOLVED SPECTROSCOPY OF LASER-GENERATED MICROPLASMAS.

E. Archbold, D. W. Harper, and T. P. Hughes (National Physical Laboratory, Light Div., Teddington, Middx., England).

British Journal of Applied Physics, vol. 15, Nov. 1964, p. 1521-1526
13 refs.

Time-resolved spectroscopic observations of the radiation emitted from the target area when the output from a 1-mw Q-switched ruby laser is focused on a solid surface. A small highly ionized plasma is formed near the target surface. During each pulse of laser light strong continuous emission occurs, extending well into the UV. Ge IV and Sn IV lines have been recorded; these appear only briefly. Less highly ionized atoms are more persistent; lines from neutral atoms are emitted for several microseconds after the laser pulse ends. It is shown that absorption of the laser beam by free-free transitions is an effective plasma-heating process above a critical take-off temperature which depends on the laser beam power density and frequency and on the ionization potential of the target material. (Author) W. M. R.

A65-10507

UNIFIED CONSIDERATION OF WAVE AMPLIFICATION IN MOVING MEDIA.

Toshimitsu Musha (Nippon Telegraph and Telephone Public Corp., Electrical Communication Laboratory, Tokyo, Japan).

Journal of Applied Physics, vol. 35, Nov. 1964, p. 3273-3279.
24 refs.

Proposal of a new type of amplifier, an inverse maser. By quantization of wave fields, quanta of negative energy are produced when the velocity of the moving medium exceeds the phase velocity of a wave in the moving medium. Wave-amplification phenomena caused by negative quanta are classified in four types, to each of which are related several kinds of known amplification phenomenon or instability. The traveling-wave tube, two-stream instability, ultrasonic wave amplification in a CdS crystal, roton excitation in superfluid helium, and beam-plasma instability are among the concepts thus classified. D. H.

A65-10511

GIANT PULSE LASER ACTION AND PULSE WIDTH NARROWING IN NEODYMIUM-DOPED BORATE GLASS.

J. R. Sanford, J. H. Wenzel (General Electric Co., Ithaca, N. Y.), and G. J. Wolga (Cornell University, Ithaca, N. Y.).

Journal of Applied Physics, vol. 35, Nov. 1964, p. 3422, 3423.
5 refs.

Experimental data and observations of: (1) threshold energy vs output mirror reflectance in the giant pulse mode, (2) threshold energy vs output mirror reflectance in the pulsed mode, (3) giant pulse energy output vs energy input as a function of output mirror reflectance, and (4) giant pulse narrowing as a function of input energy. When the laser was driven well above threshold, the width of the giant pulse seemed to be independent of the prism switch rotation speed, which was varied from approximately 250 to 1000 cps. It is believed that the results (which are expressed in tabular form and are thought to show reasonable correlation with the analytical work of Wagner and Lengyel) indicate that the giant pulse width is determined by the mean photon lifetime in the optical resonator and the level of inversion. D. H.

A65-10548

A SIMPLIFIED METHOD FOR THE ANALYSIS OF SELF-CROSS-RELAXATION MASERS.

Huang Wu-Han and Lin Fu-Cheng (Academia Sinica, Institute of Electronics, Peking, Communist China).

Physical Society, Proceedings, vol. 84, Nov. 1964, p. 643-659.
8 refs.

A simplified method of analyzing the effect of self-cross-relaxation on maser performance. The method is said to permit calculations to be made for any four-level system involving not more than triple cross-relaxation processes. Some operative modes are indicated in which it is thought possible to improve performance. As illustrative examples, some typical design considerations and results are given for X-band and S-band ruby-cavity masers. (Author) D. H.

A65-10593

GAS LASER FOR THE VISIBLE AND THE INFRARED REGION [PLYNOVÝ MOLEKULÁRNÍ GENERÁTOR SVĚTLA PRO VIDITELNOU A INFRACERVENOU OBLAST].

F. Petrá, B. Popela, J. Kršek, M. Ruběš, and Z. Veselá (Československá Akademie Věd, Ústav Přístrojové Techniky, Brno, Czechoslovakia).

Jemná Mechanika a Optika, vol. 9, Sept. 1964, p. 269-275, 282.
30 refs. In Czech.

Description of the construction of He-Ne lasers yielding emissions of the visible line $0.6328 \mu\text{m}$, and the infrared lines $1.1523 \mu\text{m}$ and $3.39 \mu\text{m}$. The action of a laser system is described, and some application areas are considered. The solution of the individual system parts of two types of gas lasers, lasers having resonators 1265 and 800 mm in length, is discussed. The properties of these lasers are noted, and experimental results are included. M. L.

A65-10665

THEORETICAL AND EXPERIMENTAL INVESTIGATION OF AIR BREAKDOWN UNDER THE ACTION OF A LASER BEAM [ETUDE EXPERIMENTALE ET THEORIQUE DU CLAQUAGE DE L'AIR SOUS L'ACTION D'UN FAISCEAU LASER].

Michel Berry, Yves Durand, Pierre Nelson, and Pierre Veyrie. Académie des Sciences (Paris), Comptes Rendus, vol. 259, no. 15, Oct. 12, 1964, p. 2401-2403. In French.

Investigation of the existence of multiphotonic processes to account for the breakdown of air under the action of a ruby laser beam. It is stated that a few millimeters of air at atmospheric pressure are sufficient to absorb 80% of the energy of a focused beam of a released laser. A figure shows a very distinct threshold marking the appearance of air breakdown visible to the naked eye, and indicating the existence of a relation between air ionization and light absorption. M. M.

A65-10680

APPLICATION OF THE LASER IN THE DETERMINATION OF INTERNAL STRESSES VARIABLE AS A FUNCTION OF TIME [SUR UNE APPLICATION DU LASER A LA DETERMINATION DES TENSIONS INTERIEURES VARIABLES EN FONCTION DU TEMPS]. Henri Haeggi and Walter Schumann (Ecole Polytechnique Fédérale, Zürich, Switzerland).

Académie des Sciences (Paris), Comptes Rendus, vol. 259, no. 16, Oct. 19, 1964, p. 2599-2602. 8 refs. In French.

Demonstration of the advantage of using in photoelasticity a laser, rather than an ordinary spectrum lamp, for the interferometric determination of internal stresses variable as a function of time. It is stated that, thanks to the fact that the laser is an intense and very monochromatic light source, it is possible to study rapidly varying stresses. M.M.

A65-10902 #

THE STABILITY OF SINUSOIDAL OSCILLATIONS OF A MASER [OB USTOICHIVOSTI SINUSOIDAL'NYKH KOLEBANII MOLEKULIARNOGO GENERATORA].

V. N. Lugovoi (Akademiia Nauk SSSR, Fizicheskii Institut, Moscow, USSR).

Radiofizika, vol. 7, no. 4, 1964, p. 792-796. 6 refs. In Russian.

Derivation of expressions for determining the regions of stability and instability of sinusoidal oscillations of a maser for the case in which the frequency of the emission line does not coincide with the natural frequency of the resonator. J.R.

A65-11027 #

THE SPECTRUM OF A RUBY LASER WITH EXTERNAL SPHERICAL MIRRORS [SPEKTR OPTICHESKOGO GENERATORA NA RUBINE S VNESHNIMI SFERICHESKIMI ZERKALAMI].

V. K. Koniukhov, L. A. Kulevskii, A. M. Prokhorov, and A. K. Sokolov (Akademiia Nauk SSSR, Fizicheskii Institut, Moscow, USSR).

Akademiia Nauk SSSR, Doklady, vol. 158, Oct. 11, 1964, p. 824-826. 12 refs. In Russian.

Investigation, by means of a Fabry-Perot interferometer, of the emission spectrum of a ruby laser with external spherical mirrors operating in the regime of nondamping intensity fluctuations and under quasi-steady conditions of generation. It is shown that, unlike a ruby laser with plane mirrors generating simultaneously several spectral components with frequencies varying chaotically with time, within the spectral interval $\sim 1 \text{ cm}^{-1}$, the spectrum of the ruby laser with external spherical mirrors consists of a single component with a width of no more than 0.1 cm^{-1} . J.R.

A65-11089

TIME-RESOLVING INFRARED POLARIZATION ANALYZER FOR THE 2- TO 4- μ RANGE.

John P. Craig, Robert F. Gribble, and Arwin A. Dougal (Texas, University, Dept. of Electrical Engineering, Austin, Tex.).

Review of Scientific Instruments, vol. 35, Nov. 1964, p. 1501-1503. 5 refs.

USAF-NSF-supported research.

Report of the increased efficiency of a time-resolving infrared polarization analyzer using maser infrared radiation. With a He-Ne maser at 3.39μ , angular resolution of approximately $1/2^\circ$ for polarization oscillations as high as 1 Mc are obtained for a 1/2-mw emission. Air-germanium interfaces, uncooled InAs photovoltaic detectors, and 10-Mc-bandwidth preamplifiers are employed in the instrument. It is concluded that the analyzer makes possible the quantitative space-and-time resolved measurement of the Faraday rotation of a polarized maser beam propagated through a transient, dense, high-temperature deuterium plasma in an intense magnetic field. M.L.

A65-11099

XENON FLASH LAMP FOR LASER PUMPING IN LIQUID NITROGEN.

J.W. Tucker and J.N. Bradford (U.S. Naval Research Laboratory, Washington, D.C.).

Review of Scientific Instruments, vol. 35, Nov. 1964, p. 1615, 1616.

Discussion of the use of argon-xenon flashlamps cooled to the temperature of liquid nitrogen for laser pumping. It is found that the difficulty arising because xenon is solid at this temperature is overcome by using an argon-xenon mixture. The partial pressures that are used at room temperature are 100 torr argon and 600 torr xenon and at 77°K are 100 torr argon and 3×10^{-3} torr xenon. Performance of the lamp is compared with a similar xenon flashlamp operated at room temperature and is found to be substantially the same with respect to emission and spectral distribution. It is concluded that xenon lamps may be operated in liquid nitrogen if some argon is added to the xenon. M.L.

A65-11116 #

PROPOSAL FOR SEMICONDUCTOR LASER WITH WIDE-GAP EMITTERS.

T. Pečený (Research Institute of Radiocommunications, Prague, Czechoslovakia).

Physica Status Solidi, vol. 6, no. 3, 1964, p. 651-664. 17 refs.

Estimate of the concentration of injected carriers necessary for inversion in p-type GaAs using the known band structure. It is shown that an N-p-P structure with two wide-gap emitters (N and P) can improve the injection efficiency to such an extent that almost all the current flowing through the laser results in recombination in the inverted region. A system is proposed which, besides employing N-p-P structure, uses semi-insulating GaAs to reduce the junction area. (Author) W. M. R.

A65-11316

INTERFERENCE FRINGES IN LASER SYSTEMS.

C. L. Rudder and D. A. Hayler (Douglas Aircraft Co., Inc., Missile and Space Systems Div., Advance Space Technology, Electronics Branch, Santa Monica, Calif.).

IN: NATIONAL ELECTRONICS CONFERENCE, 20TH, CHICAGO, ILL., OCTOBER 19-21, 1964, PROCEEDINGS, VOLUME 20.

Chicago, National Electronics Conference, Inc., 1964, p. 2-7. 7 refs.

Research supported by Douglas Aircraft Co., Inc.

Mathematical description of the rings formed by various lens configurations, including the spherical laser mirror, and presentation of experimental data obtained with He-Ne CW laser. The effects of this phenomenon on several systems are discussed. A theoretical model involving double ray interference is established and compared with observation. The conditions under which this phenomenon can be observed, namely, a laser source incident on at least one approximately axially aligned curved optical surface, are presented. The harmful effects of this phenomenon on various laser systems, such as communication and plasma diagnostics, are discussed. It is concluded that, with proper precautions, any deleterious effects of these rings can be sufficiently reduced so as to be insignificant. M.M.

A65-11324

INTERACTION OF HIGH POWER LASER RADIATION WITH ABSORBING SURFACES.

John F. Ready (Honeywell, Inc., Research Center, Hopkins, Minn.).

IN: NATIONAL ELECTRONICS CONFERENCE, 20TH, CHICAGO, ILL., OCTOBER 19-21, 1964, PROCEEDINGS, VOLUME 20.

Chicago, National Electronics Conference, Inc., 1964, p. 67-71.

6 refs. Presentation of methods for calculating the effects produced when a laser pulse of a given shape and power density is absorbed at an opaque surface. The temperature rise and the depth of the vaporized hole can be estimated by these methods. It is stated that there is good agreement between these results and experimental data from electron emission, from direct measurement of hole depth, and from photographs of the vaporized plume. A table shows the depth of metals vaporized by different laser pulses. (Author) M. M.

A65-11325

AN OPTICAL STUDY OF PERFORMANCE LIMITATIONS OF PLASMA LASERS.

Sol Aisenberg (Space Sciences, Inc., Waltham, Mass.).
IN: NATIONAL ELECTRONICS CONFERENCE, 20TH, CHICAGO, ILL., OCTOBER 19-21, 1964, PROCEEDINGS, VOLUME 20, Chicago, National Electronics Conference, Inc., 1964, p. 72-77, 17 refs.

Measurement of the single pass gain of the 6328-Å red laser line in He-Ne plasmas, as a function of partial pressures and of tube current. The reduction of gain was studied for various partial pressures for additions of argon, xenon, and krypton. It is stated that single pass absorption measurements for 6328 Å in neon at higher currents and pressures indicated that the lower laser level population increased faster than a linear function of current. The variation of fluorescent radiation from the upper laser level for a He-Ne plasma suggested that the helium metastable level was depopulated by electron quenching. The dependence of electron temperature upon tube radius and pressure was shown to be through ambipolar diffusion. Cumulative processes in plasmas were shown to be important, both for excitation and for ionization. A number of possible methods for increasing temperature (or energy) in plasmas are discussed. (Author) M. M.

A65-11334

HIGH SPEED COUNTING FOR LASER RANGING TO ONE FOOT RESOLUTION.

G. Jansen, J. V. O'Hern, and H. R. Schindler (General Electric Co., Command Systems Div., Electronics Laboratory, Syracuse, N. Y.).

IN: NATIONAL ELECTRONICS CONFERENCE, 20TH, CHICAGO, ILL., OCTOBER 19-21, 1964, PROCEEDINGS, VOLUME 20, Chicago, National Electronics Conference, Inc., 1964, p. 257-262. Research supported by General Electric Co.

Description of an electronic system for precise time-interval measurements. It was developed for a portable laser range finder to measure distances up to ten miles with a resolution of 1 ft. The results of approximately 50 measurements of the differences between theodolite and range-finder measurements show that the RMS error of the range finder is on the order of 1 ft. The Vernier approach to time-interval measurements is shown to be capable of measuring such intervals with high accuracy and simple means. The approach is said to be adaptable to systems with even higher time resolution, on the order of a fraction of a nanosec. Also, extension to measurements of extremely long time intervals is possible. It is noted that, if, in that case, the absolute error should remain in the nanosec region, a double Vernier system can be designed, measuring the phase to a reference clock at the start and at the end of the interval. M. M.

A65-11362

A LASER SYSTEM FOR WELDING AND MACHINING AEROSPACE METALS.

Robert A. Kaplan (TRG, Inc., Melville, N. Y.).

IN: NATIONAL ELECTRONICS CONFERENCE, 20TH, CHICAGO, ILL., OCTOBER 19-21, 1964, PROCEEDINGS, VOLUME 20, Chicago, National Electronics Conference, Inc., 1964, p. 929-933. Contract No. AF 33(657)-8799.

Review of the physical principles involved in energy transfer from a laser beam, and description of the principal laser-beam requirements and of the TRG laser system, with the emphasis on control techniques. Experimental results using the laser welding system are presented. The advantage of laser-beam processes is stated to be the extremely high energy densities and the precise control of the beam size and shape which are available. Because of these advantages, it appears that laser-beam processes will find considerable application in specialized machining and welding operations, involving either extremely high melting-temperature materials, or very small and critical dimensions. M. M.

A65-11451

MEASUREMENT OF FREE AIR STREAM AIR DENSITY BY MEANS OF A LASER BEAM.

Arnold Nudell and Lee Benson (Litton Systems, Inc., Woodland Hills, Calif.).

IN: INTERNATIONAL SPACE ELECTRONICS SYMPOSIUM, LAS VEGAS, NEV., OCTOBER 6-9, 1964, RECORD.

New York, Institute of Electrical and Electronics Engineers, Space Electronics and Telemetry Group, 1964, p. 2-e-1 to 2-e-7. 6 refs.

Discussion of a system that eliminates the difficulties encountered when the pilot of a re-entry craft uses conventional systems for measuring the free-stream density in the atmosphere. The system employs a light-backscattering principle based on Rayleigh scattering theory. This laser backscattering principle can be applied to craft at altitudes approaching the free molecular regime (up to one million feet). The theory, instrumentation, procedure, and experimental verification of the system are described. V. Z.

A65-11540

ACHIEVEMENTS AND POSSIBILITIES OF LASER TECHNIQUE - A SURVEY [DOSTIZHENIYA I VOZMOZHNOСТИ TEKHNIKI LAZEROV - OBZOR].

S. A. Ziul'ko.

Radiotekhnika, vol. 19, Oct. 1964, p. 3-8. 5 refs. In Russian.

A review of the latest progress in laser technique emphasizing the monochromaticity and the coherence of emission in time and space as the remarkable properties of lasers which produce energy flows of extremely high density. More important fields of application of lasers are specified as: (a) highest-precision measuring technique allowing finest physical experimentation exemplified by the Michelson-Morley classical light speed-measurement and the Sagnac's discovery of the Earth's absolute motion, and (b) communications and space telemetering. Various types of laser are described. V. Z.

A65-11708

CONTINUOUS-WAVE LASER ACTION ON VIBRATIONAL-ROTATIONAL TRANSITIONS OF CO₂.

C. K. N. Patel (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Physical Review, 2nd Series, vol. 136, Nov. 30, 1964, p. A1187-A1193. 16 refs.

Observation of cw laser action obtained on a number of rotational transitions of the $\Sigma_u^+ - \Sigma_g^+$ vibrational band of CO₂ around 10.4 and 9.4 μ . The laser wavelengths are identified as the P-branch rotational transitions from P(12) to P(38) for the 00⁰₁-10⁰₀ band and from P(22) to P(34) for the 00⁰₁-02⁰₀ band. Strongest laser transition occurs at 10.6324 μ (vacuum). A cw power output of about 1 mw has been measured. All these laser transitions can also be made to oscillate under pulsed discharge conditions with a small increase in the peak laser power output. No R-branch transitions have been seen to oscillate either under cw or pulsed discharge conditions. It is stated that the wavelength measurements are in reasonable agreement with earlier measurement of the bands in absorption, but there are slight differences. These are ascribed to possible pressure-dependent frequency-shift effects. A study has been made of the time dependence of the laser output under pulsed excitation, and some conclusions about possible excitation processes are given. Theoretical interpretation given earlier for laser action on vibrational-rotational transitions is discussed in a generalized form. The theory is applicable to both the linear polyatomic molecules and the diatomic molecules. (Author) M. M.

A65-11709

HANLE EFFECT IN THE HE-NE LASER.

W. Culshaw and J. Kannelaud (Lockheed-Aircraft Corp., Lockheed Missiles and Space Co., Research Laboratories, Palo Alto, Calif.).

Physical Review, 2nd Series, vol. 136, Nov. 30, 1964, p. A1209-A1221. 14 refs.

Research supported by the Lockheed Independent Research Program.

Consideration of the effect of small magnetic fields on the degenerate levels of the 1.153- μ He-Ne laser transition, in the region where the transitions overlap and coherence is imparted by the excitation and induced-emission processes. Perturbation equations for the phenomena are solved by a small-signal approximation, and the probability amplitudes summed coherently to give the resultant intensity and polarization changes. It is stated that, for a symmetrical disposition of the laser frequency with respect to the Zeeman

transitions, the polarization remains linear until the states separate beyond the natural linewidth, but rotates with increasing magnetic field. Rotations around 45° are indicated for axial and transverse magnetic fields less than one gauss. With the laser frequency asymmetric with respect to the transitions, elliptical polarization occurs. Investigations on a short planar laser show that such a rotation does take place when small axial magnetic fields are applied, and that the polarization remains linear. Some variation with the rf level of excitation is encountered, and there are similar effects at a higher value of dc magnetic field. Studies with sawtooth and ac magnetic fields show the modulation and harmonics which result when the periodic rotation is passed through an analyzer.

(Author) M. M.

A65-11794

ELECTRON TEMPERATURE IN A LASER-HEATED PLASMA.
E. Archbold and T. P. Hughes (National Physical Laboratory, Light Div., Teddington, Middx., England).

Nature, vol. 204, Nov. 14, 1964, p. 670. 6 refs.

Experimental investigation of plasma generation using a Q-switched neodymium glass laser. An estimate of the electron temperature attained in a carbon plasma is given. A number of assumptions is made, in particular that of a Maxwellian distribution of electron velocities. The expression given by Kaufman and Williams for the specific intensity, I , divided by the product of the number of densities of electrons, n_e , and of quadruply ionized carbon atoms in the ground state, n_1 , has been evaluated for the observed CV transition $2s^3S_1-2p^3P_2$ at $2270-91 \text{ \AA}$, and is plotted as a function of the electron temperature, T_e . It is stated that, taking into account geometrical considerations, the observed blackening of the spectrographic plate indicates that the specific intensity of this CV line was at least $3 \times 10^{11} \text{ erg cm}^{-3} \text{ sec}^{-1}$. An extreme upper limit of 1021 cm^{-3} for n_1 is obtained from the volume and density of the graphite removed from the target by the laser pulse, and the volume of luminous plasma emitting CV light. M. M.

A65-11933

THE RUBY OPTICAL MASER.

Chih-Chiang Wang.

Acta Physica Sinica, vol. 20, Jan. 1964, p. 63-71. 16 refs. In Chinese.

Discussion of the properties of the resonant cavity, the operating conditions, and the radiation output of optical pumping lasers. Factors affecting the operation and the resultant emission are analyzed in detail. Standards for evaluating the resonant cavity and the active medium are described. Cavity constructions are proposed for limiting the resonance to one or a few modes. Such limitations are seen to permit increases of several orders of magnitude in the photon degeneracy or brightness per frequency unit. Experiments on a laboratory maser are described. Interpretations of the observed angular distribution of the emitted light are presented that are believed to clarify other previously published experimental results. (Author) W. M. R.

A65-12035

INCREASED METEOROLOGICAL TARGET DETECTION BY X-BAND RADAR SET AN/MPS-34 USING MASER PREAMPLIFIER.

Raymond L. Robbiani (U.S. Army, Electronics Command, Electronics Research and Development Laboratories, Fort Monmouth, N. J.).

IN: WORLD CONFERENCE ON RADIO METEOROLOGY, INCORPORATING THE ELEVENTH WEATHER RADAR CONFERENCE, BOULDER, COLO., SEPTEMBER 14-18, 1964.

Conference sponsored by the Inter-Union Committee on Radio-Meteorology (International Scientific Radio Union /URSI/, and the International Union of Geodesy and Geophysics /UGGI/), American Meteorological Society, Central Radio Propagation Laboratory, National Bureau of Standards, and U.S. Weather Bureau. Boston, American Meteorological Society, 1964, p. 310-315.

Description of the use of an X-band maser preamplifier to increase the sensitivity of an AN/MPS-34 weather radar. The sensitivity and noise figure for the radar with and without the maser are compared. Preliminary observations to determine improvements in storm detectability with the maser are described. Radar sensitivity is improved by at least 12.5 db, and corresponding increases in detectability are found. P. K.

A65-12051

METEOROLOGICAL OBSERVATIONS WITH LIDAR.

Myron G. H. Ligda (Stanford Research Institute, Menlo Park, Calif.).

IN: WORLD CONFERENCE ON RADIO METEOROLOGY, INCORPORATING THE ELEVENTH WEATHER RADAR CONFERENCE, BOULDER, COLO., SEPTEMBER 14-18, 1964.

Conference sponsored by the Inter-Union Committee on Radio-Meteorology (International Scientific Radio Union /URSI/, and the International Union of Geodesy and Geophysics /UGGI/), American Meteorological Society, Central Radio Propagation Laboratory, National Bureau of Standards, and U.S. Weather Bureau. Boston, American Meteorological Society, 1964, p. 482-489. 17 refs.

Research supported by the Stanford Research Institute, Lear Siegler, Inc., and Navy.

Description of an experimental lidar (light-detecting and ranging) device employing a ruby laser for meteorological observations. Atmospheric attenuation, scattering, and interference phenomena affecting the use of lidars for weather observations are discussed. Instrumental considerations for a lidar transmitter and receiver are reviewed. Possible applications of pulsed lidars are described, and include cloud observations, cloud development and composition studies, visibility determinations, and observations of small-scale atmospheric motions. Some typical observations obtained with a ruby lidar are presented. P. K.

A65-12052

THE USE OF COHERENT LIGHT IN GATHERING SIGNIFICANT METEOROLOGICAL DATA.

Richard H. McFarland (Ohio University, Athens, Ohio).

IN: WORLD CONFERENCE ON RADIO METEOROLOGY, INCORPORATING THE ELEVENTH WEATHER RADAR CONFERENCE, BOULDER, COLO., SEPTEMBER 14-18, 1964.

Conference sponsored by the Inter-Union Committee on Radio-Meteorology (International Scientific Radio Union /URSI/, and the International Union of Geodesy and Geophysics /UGGI/), American Meteorological Society, Central Radio Propagation Laboratory, National Bureau of Standards, and U.S. Weather Bureau. Boston, American Meteorological Society, 1964, p. 494-497. 19 refs.

Brief review of possible uses of lasers in meteorological investigations. Applications discussed include the measurement of relative humidity and the determination of particle content over a given path, and the optical radar mapping of eddy profiles. P. K.

A65-12084

ON THE RADIATION OF MOLECULES IN A DETUNED CAVITY AND THE PHENOMENA OF DOUBLE-CAVITY MASERS.

Tie-Cheng Li and Li-Zhi Fang.

Acta Physica Sinica, vol. 20, Aug. 1964, p. 753-760. 9 refs. In Chinese.

Investigation, by a rigorous method of quantum mechanics, of the radiation behavior of the molecules in a detuned cavity. The experimental finding of Higa, that when the detuning of the first cavity reaches a critical value, the second cavity suddenly breaks out into oscillations at the center frequency of the molecules, is interpreted. A formula is obtained for the critical detuning which leads to the sudden oscillation. The experimental curves obtained by Strakhovskii and Tatrenkov about the dependence of the radiation power of the molecules in the second cavity on frequency detuning are qualitatively interpreted. (Author) M. M.

A65-12091**LASER INTERFEROMETER.**

Fred H. London (Cutler-Hammer, Inc., Airborne Instruments Laboratory Div., Deer Park, N. Y.).

Instruments and Control Systems, vol. 37, Nov. 1964, p. 87-89.

Description of the Absolute Interferometric Laser (AIL) calibrator, which makes possible laboratory length-measuring accuracy in an industrial environment. The device is a double-beam type of interferometer which will operate over a distance of 100 in. The accuracy is 0.00003" or 0.00001" per foot, whichever is larger. A gas laser source and its related optics and photodetectors are rigidly connected, and the unit is mounted to the frame of the machine to be checked out. The interference fringes generated by moving a reflector mounted on the moving portion of this machine are detected by photosensitive devices and counted by a high-speed forward-backward digital counter, and the fringe count is converted into inches. Problems encountered in developing the device are discussed.

F. R. L.

A65-12176**PUMP ENERGY ABSORPTION IN A RUBY ROD.**

G. Lampis, C. A. Sacchi, and O. Svelto (Milano, Politecnico, Istituto di Fisica, Milan, Italy).

Applied Optics, vol. 3, Dec. 1964, p. 1467-1470, 11 refs.

Research supported by the Italian National Research Council.

Experimental measurement of the radial distribution of the pump energy absorbed within a ruby rod when pumped by a helical flashtube. The measurement is performed by taking near-field pictures of the emission pattern of the red fluorescence of the ruby. The emission pattern in this case is a visual reproduction of the energy absorbed at each point of the rod. The three cases considered are: (1) ruby rod in air, (2) ruby rod covered by a cylindrical sheath of water, and (3) ruby rod covered by a cylindrical sheath of benzyl benzoate. The influence of the ground-state depopulation (due to the pumping) on the radial distribution is also studied. Experimental curves for the energy density are compared with theoretical curves obtained from the theory developed in a previous paper. The agreement is thought to be reasonably good since the theoretical curves did not differ from the experimental ones by more than 20%.

(Author) D. H.

A65-12177**A SCANNING SPHERICAL MIRROR INTERFEROMETER FOR SPECTRAL ANALYSIS OF LASER RADIATION.**

R. L. Fork, D. R. Herriott, and H. Kogelnik (Bell Telephone Laboratories, Inc., Murray Hill, N. J.).

Applied Optics, vol. 3, Dec. 1964, p. 1471-1484, 26 refs.

Results of a theoretical and experimental investigation of a scanning spherical mirror interferometer (SSMI) designed specifically for laser-radiation analysis. It is shown that the high degree of spatial coherence and monochromaticity of laser radiation makes it possible to excite individual interferometer modes selectively. A theory of single-mode excitation is presented, and a specific example is treated. The mechanical construction of the SSMI and the dynamics of the scanning system are described. The capability of the instrument for observation of laser mode separation, amplitudes, and frequency shifts is illustrated by specific experiments. It is shown that the instrument can easily be used in both the visible and the IR. Results of simultaneous observations of beats between laser modes with an RF spectrum analyzer and of the laser optical field with the scanning interferometer are given, and it is shown that the combined system, in certain cases, will permit determination of the relative phases of the laser modes. Experiments illustrating the use of the scanning interferometer for observation of mode competition and the effects of magnetic fields on laser output are recounted, as is also the operation of an active scanning interferometer with which resolving powers of 2.5×10^9 and finenesses of 1040 were obtained. Effects of coupling between laser and interferometer are shown, and a polarization isolator for decoupling is described.

(Author) D. H.

A65-12178**MODES OF OPTICAL MASER CAVITIES WITH ROOF-TOP AND CORNER-CUBE REFLECTORS.**

David L. Bobroff (Raytheon Co., Research Div., Waltham, Mass.).

Applied Optics, vol. 3, Dec. 1964, p. 1485-1487.

Description of some of the unique properties of Fabry-Perot cavities formed with roof-top and corner-cube reflectors including comparisons with cavities formed with plane-parallel reflectors. Only simple geometrical and analytical considerations are used. It is concluded that a cavity with a plane mirror has only standing waves; that a cavity formed from two corner cubes or a corner cube and a roof top has, in general, only traveling waves; and that a cavity formed from two roof tops always has standing waves and, for proper orientations of the roof tops, also has traveling waves. The results are said to have application in laser system design.

D. H.

A65-12179**INTERFEROMETRIC MEASUREMENTS OF RAPID PHASE CHANGES IN THE VISIBLE AND NEAR INFRARED USING A LASER LIGHT SOURCE.**

Rudolf G. Buser and Johann J. Kainz (U. S. Army, Electronics Command, Electronics Research and Development Laboratory, Fort Monmouth, N. J.).

Applied Optics, vol. 3, Dec. 1964, p. 1495-1499, 10 refs.

Determination of electron densities and other parameters in a plasma by means of Michelson interferometric measurements using a He-Ne laser beam to penetrate the plasma. It is expected that the Michelson interferometer - working in the IR or visible - will provide a powerful diagnostic tool for the determination of characteristic plasma properties with excellent spatial resolution and (in comparison to Fabry-Perot systems) somewhat relaxed requirements for the quality of the windows of the plasma vessel. There is said to be sufficient energy available to use photomultiplier or streak-camera detection and to overcome the background radiation of the plasma if the proper filters are used.

D. H.

A65-12181**ON THE POSSIBILITY OF USING CONICAL REFRACTION PHENOMENA FOR LASER BEAM STEERING.**

Robert P. Burns (USAF, Systems Command, Research and Technology Div., Electromagnetics Laboratory, Rome Air Development Center, Electro-Optics Section, Griffiss AFB, N. Y.).

Applied Optics, vol. 3, Dec. 1964, p. 1505, 1506.

Theoretical investigation of a technique of steering a linearly polarized laser beam by changing the orientation of the beam polarization with an electro-optic crystal and positioning the beam according to the polarization by means of a biaxial crystal. A quarter-wave plate is used between the electro-optic crystal and the biaxial crystal to correct for the elliptical polarization resulting from transmission through the electro-optic crystal. This recreates the linearly polarized light which impinges on the biaxial crystal. Equations governing the polarization control are presented, and scan angle and resolution are discussed. It is suggested that the circular scan produced can be converted to a linear deflection by means of cylindrical lenses or fiber optics. An experimental program has reportedly been initiated to verify these theoretical expectations.

D. H.

A65-12282 #**LUMINESCENCE PRODUCED BY THE ACTION OF A RUBY LASER BEAM IN SODIUM URANYL ACETATE CRYSTALS [SVITINNA, SHCHO VINIKAE PID DIEU PUCHKA RUBINOVOGO LAZERA NA KRISTALI NATRIURANILATSETATU].**

M. S. Brodin, V. M. Vatul'ov, and S. V. Zakreva'kii (Akademiia Nauk Ukrain's'koi RSR, Kiev, Ukrainian SSR).

Ukrains'kii Fizichnii Zhurnal, vol. 9, Oct. 1964, p. 1150, 1151, 6 refs in Ukrainian.

Investigation of a spectrum generated by the action of a focused ruby laser beam in single crystals and crystalline powder of sodium uranyl acetate. Two types of spectrum, a band-type spectrum and a structureless spectrum, are revealed. The spectra are described and diagrammed. V. Z.

A65-12288 #

USE OF LASERS IN PLASMA DIAGNOSTICS [ISPOL'ZOVANIE OPTICHESKOGO KVANTOVOGO GENERATORA DLIA DIAGNOSTIKI PLAZMY].

A. N. Zaidel', G. M. Malyshev, and G. V. Ostrovskaya. IN: PLASMA DIAGNOSTICS - COLLECTION OF ARTICLES [DIAGNOSTIKA PLAZMY - SBORNIK STATEI].

Edited by B. P. Konstantinov. Moscow, Gosatomizdat, 1963, p. 31-35. 6 refs. In Russian.

Determination of the region of applicability of a method proposed by Wessel, Tothenberg, Zende, and Hughes for measuring both the electron concentration and electron distribution function with respect to velocity by scattering light from a ruby laser on free plasma electrons. Expressions are derived for computing the maximum and the minimum electron concentrations for laser radiation energies ranging from 0.5 to 500 joules (10^3 to 10^6 watt). A diagram is presented, illustrating that the region of electron concentrations and temperatures in which the method is applicable becomes wider as the laser energy and power increase. J. R.

A65-12289 #

POSSIBILITY OF USING LASERS IN PLASMA DIAGNOSTICS [O VOZMOZHNOСТИ PRIMENENIYA LAZEROV DLIA DIAGNOSTIKI PLAZMY].

V. V. Korobkin. IN: PLASMA DIAGNOSTICS - COLLECTION OF ARTICLES [DIAGNOSTIKA PLAZMY - SBORNIK STATEI].

Edited by B. P. Konstantinov. Moscow, Gosatomizdat, 1963, p. 36-41. 10 refs. In Russian.

Discussion of the possibility of using lasers for determining electron concentrations and temperatures in plasmas. One of the methods considered utilizes continuous gaseous lasers as energy sources in plasma investigations by interferometers (Fabry-Perot). Formulas are derived for determining the maximum electron concentration which can be measured by this technique. Another method which also utilizes continuous gaseous lasers for determining the electron concentration, is briefly described. In this case, the plasma being investigated is introduced into the laser resonator. Variations in the electron concentrations cause changes in the refractive index of the plasma and, consequently, in the optical length of the laser resonator. In addition to these two interference methods, the use of lasers for determining plasma parameters from the Thomson scattering of light is also illustrated. In this technique, the electron temperature is determined directly by measuring the line halfwidth of the scattered light, and the electron concentration by measuring the absolute intensity of the scattered light. Some of the problems associated with the signal-to-noise ratio are discussed. J. R.

A65-12351

LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964. 103 p. \$5.60.

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THE GENERATION OF MICROWAVE RADIATION IN A LASER-PUMPED RUBY. A. J. Alcock and R. Williamson (Oxford University, Oxford, England), p. 7-1, 7-2. [See A65-12358 03-16]

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A65-12352 *

USE OF A C.W. GAS LASER FOR VERY LONG DISTANCE MEASUREMENTS.

A. H. Cook (National Physical Laboratory, Standards Div., Teddington, Middx., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964, p. 1-1 to 1-3.

Discussion of techniques for obtaining highly accurate geodetic observations by using a CW laser to make distance measurements between ground stations and a high satellite. By employing a polarization-modulated CW laser to direct a narrow beam of about 1 μ wavelength at a high satellite and by reflecting the beam from cube-corner reflectors or retransmitting it from a laser in the satellite, it is believed that power levels of the order 1 μ W will be available from a collecting mirror of 10⁶cm² area. The effects of interference from skylight and the choice of wavelength and modulation are also discussed.

D.H.

A65-12353 #

SPECTROSCOPIC INVESTIGATIONS OF GALLIUM ARSENIDE INJECTION LASERS.

W. Taylor (International Telephone and Telegraph Corp., Standard Telecommunication Laboratories, Ltd., Harlow, Essex, England). IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964, p. 2-1, 2-2.

Discussion of some characteristics of the GaAs laser which are believed to be hitherto unreported. In an experiment involving a standard GaAs laser immersed in liquid helium at 4°K and an Ebert type scanning spectrometer with a resolution of 1/10 Å , the effects of operating current on intensity and wavelength were studied. It is indicated that when the 140-ma threshold is reached, the first single

mode is clearly displaced to the long wavelength side of the broad spontaneous emission peak. As the current is raised, additional modes appear on the high energy side of the first mode and will dominate it as the current is increased further. At around 300 ma, a reversal is seen to occur and the lower energy modes regain their original superiority and additional modes at lower energy appear. At about 500 ma, the modes disappear abruptly and only the spontaneous emission remains. The existence of this upper threshold is attributed to the heating effects of the applied current. It is considered possible that multimoding may be reduced by employing a shorter cavity length, and the upper threshold may be increased by improving the effectiveness of the heat sink.

D.H.

A65-12355 #

A FRINGE-COUNTING INTERFEROMETER SYSTEM EMPLOYING A LASER FOR PRECISION LENGTH MEASUREMENTS.

W. R. C. Rowley (National Physical Laboratory, Standards Div., Teddington, Middx., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 4-1 to 4-3.

Description of an interferometer system which is reported to have a number of major advantages over more conventional length-measuring interferometric systems. It is indicated that by employing a gas laser light source for interferometry, it should be possible due to the extremely narrow bandwidth - to detect interference effects with path differences of thousands of miles (in contrast to the limit of a few feet with conventional monochromatic sources). Advantages in easier construction, alignment, and detection are said to accrue from the highly intense and directional nature of laser radiation. A bidirectional arrangement, slightly different from the usual Michelson configuration, is said to be most satisfactory for laser operation because it eliminates the problem of light being reflected back into the laser. A measuring machine, reportedly under construction at NPL, will be based on the bidirectional arrangement and will employ the red line from a helium-neon laser. It is expected to check length scales up to one meter in length with a discrimination of about 0.5 μ m.

D.H.

A65-12356 #

VAPORIZATION BY LASER BEAMS.

T. P. Hughes (National Physical Laboratory, Light Div., Teddington, Middx., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 5-1, 5-2. 5 refs.

Discussion of the heating processes involved when laser beams are used for micromachining and microwelding. Using Q-switching techniques, output beam powers of 10^7 watts and output energies of several joules are available. When such a beam is focused to a spot of 10^{-2} cm diameter or less, the local power density exceeds 10^{11} watts/cm², which is sufficient to vaporize the surface of any material in less than 10^{-7} sec. Even with materials with such a low boiling point as zinc (1180°K), a small plasma is generated in which multiply ionized atoms occur - suggesting a temperature of at least 20,000°K. The high surface temperature is reportedly made possible by a back-pressure of more than 10^6 atmospheres on the surface from evaporating atoms, which causes an elevation of the boiling point. Some techniques for improving laser machining efficiency are also discussed.

D.H.

A65-12357 #

GLASS LASERS.

D. W. Harper (National Physical Laboratory, Light Div., Teddington, Middx., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 6-1, 6-2.

Discussion of developments in the state of the art of producing neodymium-doped glass lasers. Interest, at present, is said to be centered on finding ways by which neodymium glass can be co-activated in such a way as to utilize more UV energy from flash tubes. Design considerations are discussed, and practical difficulties such as transmission losses due to absorption and scattering and damage caused by high-intensity radiation are described. Analysis of work by Snitzer is thought to suggest that either the homogeneous linewidth within the inhomogeneous line is large (50-100 Å) or that the cross-relaxation time for transfer of energy between neighboring ions is short.

D.H.

A65-12358 #

THE GENERATION OF MICROWAVE RADIATION IN A LASER-PUMPED RUBY.

A. J. Alcock and R. Williamson (Oxford, University, Dept. of Engineering Science, Oxford, England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 7-1, 7-2.

Description of some experiments performed with synthetic ruby in order to study the feasibility of generating millimeter wavelength radiation by laser pumping. It is indicated that the use of a giant pulse laser should cause microwave population inversion to occur in a time which is short compared with the spin-lattice relaxation time at temperatures as high as that of liquid nitrogen. Using a high Q microwave resonator, an incident laser pulse of 1 Mw intensity would reportedly produce a peak power of 20 watts at 3 cm or 600 watts at 1 mm. It is observed that materials similar to ruby but possessing considerably higher zero-field splittings would enable the laser-maser combination to provide tunable sources of high-power pulsed radiation at submillimeter wavelengths.

D.H.

A65-12359 #

RECENT ADVANCES IN THE STIMULATED RAMAN EFFECT.

E. L. Thomas (Ministry of Aviation, Signals Research and Development Establishment, Christchurch, Hants., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 9-1, 9-2. 17 refs.

Report of research since 1962 on laser-stimulated Raman spectra. Following the detection of stimulated Raman emission from the nitrobenzene of a Kerr cell, the list of active materials has expanded to include some gases and solids in addition to strong totally symmetric modes of liquids. It is reported that Zeiger et al have observed one anti-Stokes line from a nitrobenzene Kerr cell even though anti-Stokes emission does not normally build up in the Raman cavity because dispersion of the scattering medium does not allow the phase matching condition to be met between the laser and the parallel first Stokes radiation. In regard to the angles of the cones in

which the radiation appears, Szöke indicates that a nonzero solution of Maxwell's equations can be obtained when the first Stokes line is strongly directional and parallel to the laser beam. The anti-Stokes radiation can be looked upon as originating from a coherent polarization in the scattering medium which has a phase velocity higher than the velocity of light freely propagating in the medium at the same frequency and, in this respect, is similar to Cerenkov radiation. Observations of Garmire and of Thomas and Wright are also reported. D.H.

A65-12361 #

THE PRACTICAL PERFORMANCE OF SOME OPTICAL COMMUNICATION LINKS.

G. Waters and M. Dore (Ministry of Aviation, London, England).
IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Division of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section) and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 14-1, 14-2.

Discussion of the state of the art of He-Ne optical maser machining and welding. It is reported that pulsed gas lasers developed by Services Electronics Research Laboratories (SERL) can be used for machining and possibly welding, provided that their use is restricted to thin films or very small diameter wires such as are encountered in microminiature components. Machining appears to have two stages: the initial melting and vaporization, which destroys the reflectivity characteristics and the absorption of energy in an apparent blackbody absorption. The reproducibility of the pulsed-gas-laser output in terms of the power per pulse and the high pulse repetition frequencies available are considered to be an improvement on what can be achieved with ruby lasers. D.H.

A65-12362 #

FIBRE OPTICS - LIGHT GUIDES AND LASERS.

W. B. Allan (Barr and Stroud, Ltd., Glasgow, Scotland).
IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 15-1, 15-2.

Brief discussion of the principles of fiber optics including a study of the possibility of using fibers as light guides for laser beams and also as lasers. It is reported that fibers and light pipes have severe disadvantages when used to guide well-collimated beams. Decollimation occurs even in a perfect fiber if the incident light is not parallel to the fiber axis; the emerging beam, then, is in the form of a hollow cone. In practical fibers, this decollimation is increased by imperfections in the core-sheath interface and by variations in fiber diameter. It is thought that glass fibers - doped with neodymium oxide - have a promising future as lasers, especially in the field of optical computers. It is said that a major breakthrough in this field will occur when a lasing fiber of the neuristor type is developed. D.H.

A65-12363 #

CONSIDERATIONS AFFECTING THE DESIGN OF SHORT RANGE SINGLE PULSE RUBY LASER RANGEFINDERS.

J. C. Moden (Fighting Vehicles Research and Development Establishment, Chertsey, Surrey, England).
IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 16-1, 16-2.

Description of laser rangefinding experiments including a discussion of the effects of backscattering, atmospheric microturbulence, and statistical fluctuations in photoelectric emission and multiplier gain. Photocathode current due to backscatter is plotted as a function of range and visibility, and it is found that the geometry of any proposed ranging systems needs to be critically examined with a view to minimizing backscatter. A surprising result of the experiments is an inability to demonstrate an inverse square relationship between target signal and range after the effects of atmospheric attenuation have been discounted. Instead, a fair fit to an inverse linear law has been observed and there is, as yet, no satisfactory explanation of this dependence. D.H.

A65-12365 #

A COMPACT 100-WATT GaAs LASER TRANSMITTER.

K. G. Hambleton and F. E. Birbeck (Services Electronics Research Laboratories, Baldock, Herts., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 18-1, 18-2.

Description of a compact infrared transmitter using a gallium arsenide laser cooled to 77°K. The transmitter emits pulses of up to 100 watts radiated power with a rise time of 0.1 μsec and a repetition rate of up to 10 Kc/s. A photograph of the transmitter is shown. The transmitter weight is less than 300 gm and the volume only 150 cc, of which the pulse generator occupies about 80 cc. An external supply of nitrogen at 3000 psi is necessary for refrigeration, and the electrical requirements are 0.25 amps at 400 volts together with trigger pulses of about 20 volts. The laser is described, and its performance characteristics are presented. The design of the transmitting capsule had to take into account the two main problems: the provision of the electrical drive pulses and the cooling of the laser. The pulse generator and the cooling system are considered. The radiation emerges from a window in the end of the capsule, and the capsule can be used horizontally as well as vertically. M.L.

A65-12367 #

PULSED GAS LASERS.

D. M. Clunie (Services Electronics Research Laboratories, Baldock, Herts., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 20-1, 20-2. 7 refs.

Discussion of the properties of pulsed gas lasers. They are found to be intermediate between those of solid-state and CW gas lasers in that their beam properties are better than those of solid state lasers, while their output powers are much higher than those of CW gas lasers. Atomic, molecular, and ionic systems are considered. The beam properties are studied using a pulsed He/Ne laser. M.L.

A65-12368 #

A COMPACT PULSED GAS LASER FOR THE FAR INFRA-RED.

L. N. Large (Services Electronics Research Laboratories, Baldock, Herts., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Division of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 21-1, 21-2.

Discussion of the design and characteristics of a compact sealed-off far infrared source based on a 4.8-m tube. The constructional details of the device are given, and the operation of the laser is discussed. High voltage dc pulses from a line-type modulator are applied to the tungsten electrodes in the side arms. With water vapor in the tube, the onset of laser action occurs with a peak current of 16 A using a 2- μ sec pulse and the strongest oscillation occurs at 27.9 μ . The output power recorded using a Golay cell with phase sensitive detection at 10 c/s increases with increase of peak current up to 50 A, after which saturation of the peak laser output is reached. A peak power of about 0.2 watts has been measured using a thermopile, but considerably higher powers should be attained when the Q of the resonator is increased by using higher reflectance coatings on the silicon mirror. With a xenon filling, the strongest oscillations are at 5.6 μ and 9.0 μ , and the problem of clean-up is not as severe as with water vapor in the tube. At 10 cps repetition rate, the laser output is only reduced by 30% after 50 hours of operation. M.L.

A65-12369

FUNDAMENTALS OF LASER RANGING.

I.L. Davies and R. Meredith (Ministry of Aviation, Royal Radar Establishment, Malvern, Worcs., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 22-1, 22-2.

Comparison of ranging by microwave radar techniques with systems using coherent optical or near infrared radiation. The advantages and the disadvantages of laser radars are considered. The determination of the maximum range of a typical one-shot incoherent laser range finder is then studied. The dominant effect of the atmospheric attenuation on the range of detection is then shown in graph form. It is concluded that atmospheric attenuation is the dominant limitation, and that, with coherent systems, the disturbance of the phase fronts due to atmospheric turbulence could be an even more serious problem. M.L.

A65-12370

UNGUIDED OPTICAL PROPAGATION IN THE ATMOSPHERE AND UNDER-SEA.

R. Meredith (Ministry of Aviation, Royal Radar Establishment, Malvern, Worcs., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 23-1 to 23-9. 21 refs.

Discussion of atmospheric effects on laser transmission systems which vary only slowly with time, and those which occur in a time-scale measured in milliseconds. The discussion includes the absorption by the molecular constituents of the atmosphere, the scattering of radiation within the atmosphere, propagation in sea water, turbulence in the atmosphere, the fluctuation of light intensity, correlation of the fluctuations of intensity in the plane perpendicular to the beam, frequency spectrum of intensity variations, the variations in angle of arrival, and the path length and phase-change variations. The consideration of the influence of the atmospheric effects on laser transmission and of their likely magnitude leads to the conclusion that the atmosphere is completely inimical to laser transmission systems. The turbulence effects will always be present to a greater or lesser degree. Attenuation and scattering under the sea will be appreciably worse than in the air. M.L.

A65-12371

SUPERHETERODYNE RECEPTION AT OPTICAL FREQUENCIES.

F. L. Warner and M. P. Warden (Ministry of Aviation, Royal Radar Establishment, Malvern, Worcs., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 24-1 to 24-9. 69 refs.

Discussion covering the theory of optical superheterodyne detection, surveying the dozen or so different types of fast photomixers and considering the use of optical superheterodyne receivers in laser communication systems. The incorporation of an optical superheterodyne receiver in a laser radar system is studied. It is noted that superheterodyne detection at optical frequencies presents important advantages such as the preservation of Doppler shifts on coherent radar echoes, excellent selectivity, and a high degree of spatial filtering. It also makes it possible to use FM or SSBSCM in optical communication links. Background radiation, scattered sunlight, and IF amplifier noise can be made unimportant by using a sufficiently strong local oscillator signal. The associated coherence problems, however, can be serious enough to cancel the advantages. M.L.

A65-12372

A SEMICONDUCTOR LASER ARRAY.

R. F. Broom (Services Electronics Research Laboratories, Baldock, Herts., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 25-1, 25-2.

Presentation of a method of producing, in compact form, a parallel beam from an array of lasers. The collimating optics is considered, and the construction of a practical array of 10 lasers is discussed. No performance data are included since the device is still under construction. M.L.

A65-12373

Q-SWITCHED OPTICAL MASERS.

J. E. Midwinter and P. A. Forrester (Ministry of Aviation, Royal Radar Establishment, Malvern, Worcs., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 26-1, 26-2. 6 refs.

Introduction to the Q-switching process. A brief outline of the theory is presented and illustrated using the results of experiments conducted with two systems based on the Kerr cell and on the rotating mirror; the experiments concern the principle of fast and slow switching. M.L.

A65-12374

HIGH REPETITION RATE PULSED LASER OPERATION.

P. A. Forrester (Ministry of Aviation, Royal Radar Establishment, Malvern, Worcs., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 27-1, 27-2. 7 refs.

Discussion of two approaches to the development of pulsed optically pumped solid-state lasers capable of operating at a high repetition rate. One approach is to pump the laser crystal continuously as hard as possible and to obtain the pulsed output by modulating either the resonator or the gain of the crystal. The other approach is to pump the crystal to just below the level required to sustain oscillations, and then to superimpose short-duration, high-intensity pulses; this technique is a variant of the "hair trigger" method. The experiments which are discussed have been conducted with three crystal systems: $\text{Nd}^{+++}\text{-CaWO}_4$, $\text{Dy}^{++}\text{-CaF}_2$, and $\text{Tm}^{++}\text{-CaF}_2$. Pulsed laser action has been observed in all three systems in crystals grown at RRE.

M. L.

A65-12375 #**RING LASERS.**

A. F. H. Thomson (Services Electronics Research Laboratories, Baldock, Herts., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 28-1 to 28-6.

Presentation of the broad theory of the ring laser. The four known limitations - i.e., the effects of locking, the effect of circuit tuning, hole burning, and gas drift - are discussed, and approaches are presented for minimizing these limitations. The discussion includes graphs.

M. L.

A65-12376 #**FACTORS AFFECTING THE LIFE OF GAS LASERS.**

R. J. Payne (G. and E. Bradley, Ltd., London, England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 29-1, 29-2.

Discussion of the difficulties which users of lasers are likely to experience with various components of the device. Components which have the shortest life are the gas tube, the Brewster windows, and the dielectric-coated mirrors. Problems arising with these components are discussed.

M. L.

A65-12378 #**CONTINUOUS PHOTOCONDUCTIVE MIXING OF LASER MODES.**

R. J. Strain and C. C. Tooke (International Telephone and Telegraph Corp., Standard Telecommunication Laboratories, Ltd., Harlow, Essex, England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 31-1 to 31-3.

Presentation of the experimental results on the mixing of the adjacent modes of a cw, helium-neon laser in semi-insulating GaAs at room temperature. The visible, .6328-micron line has been used. The experimental device is described and the results obtained are presented. It is concluded that the results show promise of application of photoconductive mixing, both as an element in laser optical systems, and as a tool for studying high-resistivity semiconductors.

M. L.

A65-12380 #**SEMICONDUCTOR Q-SWITCHING.**

M. I. Bell (Barr and Stroud, Ltd., Glasgow, Scotland).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 34-1, 34-2.

Presentation of a simple technique for Q-switching a laser and producing very short intense bursts of illumination, which obviates the need for complicated electronics and high-speed moving parts. The approach involves the application of a semiconductor flat as one mirror of a Fabry-Perot laser cavity. Under intense laser illumination, the semiconductor-air interface undergoes a very fast increase in reflectivity resulting in a sudden increase in the "Q" of the system. This increase is sufficient to produce giant pulses. The theory of the approach is presented, the experimental device and materials are considered, and the experimental results are discussed. Two types of semiconductor mirror were used, a germanium mirror and a silicon mirror. Both types were damaged in operation.

M. L.

A65-12381 #**THE PRODUCTION OF HIGH TEMPERATURE PLASMAS BY INTENSE LASER PULSES.**

B. A. Tozer, P. R. Smy, and J. K. Wright (Electricity Council, Central Electricity Generating Board, Research Laboratories, Leatherhead, Surrey, England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 36-1 to 36-5.

Study of the feasibility of using focused laser beams to produce very-high-temperature hydrogen plasma. The restriction imposed on temperature, ion density, laser energy, plasma dimensions, and magnetic field are considered from two viewpoints. First, the temperatures and ion densities attainable with the apparatus typical of that used in previous investigations are tabulated. and, secondly, the values of the various parameters required to obtain a given temperature and ion density-containment time product of 10^{14} - necessary for fusion - are calculated and are shown graphically.

M. L.

A65-12382 #**HOLLOW METALLIC AND DIELECTRIC WAVEGUIDES FOR OPTICAL TRANSMISSION AND LASERS.**

E. A. J. Marcatili and R. A. Schmeltzer (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 37-1 to 37-3.

Study of the transmission characteristics of low loss transmission media at optical frequencies, consisting either of an ordinary circular metallic pipe of precision bore or of a hollow dielectric waveguide in which the metal is replaced with a dielectric. The propagation constants of the normal modes are determined for a hollow circular waveguide made of dielectric material or metal for application as an optical waveguide. The increase of attenuation due to curvature of the axis is also determined.

M. L.

A65-12383 #**INTERFEROMETRY WITH LASERS.**

J. W. Gates (National Physical Laboratory, Teddington, Middx., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964, p. 38-1, 38-2.

Discussion of the limitations of interferometry techniques, pointing out that these limitations would be obviated if a laser were used as a source. Two examples are presented in optical testing for which lasers have been used. These are a Fizeau test with He-Ne laser $\lambda = 6328 \text{ \AA}$, and a Burch scatter-screen interferometer with ruby laser $\lambda = 6943 \text{ \AA}$. M. L.

A65-12384 #**A HIGH POWER CW XENON LAMP FOR OPTICAL MASER PUMPING.**

J. W. Stearn and P. A. Forrester (Ministry of Aviation, Royal Radar Establishment, Malvern, Worcs., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964, p. 39-1, 39-2.

Presentation of a design for a water-cooled xenon pumping lamp capable of dissipating powers in excess of 7.5 kw in a 5-cm arc gap. The electrode assembly, cooled by a circuit separate from that of the main water-cooling jacket, is shown to be the novel feature of the design. It is found that this feature has several advantages: (1) the temperature of the electrode emissive surface can be optimized; (2) the seals between the electrodes and silica body can be maintained at room temperature, thus making it possible for the active part of the tube to be outgassed at 600°C without damaging the seals; and (3) the seals are constructed in a simpler manner than the conventional type and are more robust. Pulsed currents up to 3000 A are passed through the lamp. The distribution of the energy dissipated with the lamp running at various input levels is determined. It is found that the radiant efficiency increased with increasing input at the expense of electrode losses. M. L.

A65-12385 #**THE MEASUREMENT OF LASER POWER AND TOTAL ENERGY.**

P. J. Bateman (Ministry of Aviation, Royal Aircraft Establishment, Farnborough, Hants., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964, p. 40-1 to 40-7, 15 refs.

Review of various techniques used to measure power and energy output of the larger pulsed lasers presently available. Measurement of mean and peak power of C. W. lasers is not considered, although some of the techniques are applicable. Five means of measuring the total energy are considered: hollow-cone calorimeter, ratenest calorimeter, liquid calorimeter, photon momentum measurement, and integrated photocurrent. Three techniques of power measurement are discussed: pulse shape and energy, nonlinear effect, and photoionization. The operating characteristics of the various techniques are presented in tabular form. A summary of the methods used to attenuate or sample a beam of laser radiation is included. M. L.

A65-12386 #**CONSIDERATIONS ON THE APPLICATIONS OF SEMICONDUCTOR LASERS.**

C. Hilsam (Ministry of Aviation, Royal Radar Establishment, Malvern, Worcs., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964, p. 41-1 to 41-4, 9 refs.

Review of the conditions required for obtaining stimulated emission from a semiconductor. The review is centered on the GaAs p-n junction laser, as it is the only thoroughly studied semiconductor device, but a table is included which summarizes the characteristics of the family of semiconductor lasers. It is shown that the p-n junction type is the most promising. The response speed, in the order of 10^{-10} seconds, is considered the most remarkable feature of the junction laser. Typical operating conditions are found to be $10\text{-}\mu$ sec-width pulses at a frequency of 1 kc. Conversion efficiency is shown to fall rapidly with temperature increase. It is considered possible to choose a semiconductor laser that operates at any wavelength between 0.65 and 6 microns. Several applications are suggested. M. L.

A65-12387 #**OPTICAL MASER ACTION IN THE NEGATIVE GLOW REGION OF A COLD CATHODE GLOW DISCHARGE.**

J. Smith (Mullard, Ltd., Mullard Research Laboratories, Salfords, Surrey, England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964, p. 42-1, 42-2.

Examination of the negative glow region of a cold cathode discharge in helium-neon mixtures as a possible optical-maser oscillation. Both flat and hollow cathode configurations are used. It is shown that the flat cathode negative glow tube requires no heater or high-voltage supplies, and it is robust and cheap. The tube is suggested as a reliable low-power source of 1.153-micron radiation. It is concluded that the density and energy distribution of the electrons in the negative glow may make it suitable for optical masers requiring the production of excited ions. M. L.

A65-12388 #**SOLID STATE LASERS.**

I. L. Davies and A. C. Moore (Ministry of Aviation, Royal Radar Establishment, Malvern, Worcs., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964, p. 43-1 to 43-10, 48 refs.

Review of the present state of the art of optically pumped lasers. Particular attention is paid to the properties of materials likely to be used in practical systems. It is shown that solid-state lasers presently offer the highest peak power pulses of coherent light available. The principal disadvantage is concluded to be the poor efficiency of the lasers. The limited range of wavelengths available with solid-state lasers, as compared with gas lasers, is also considered a disadvantage. It is concluded that the applications of solid-state lasers largely lie in areas where high-power, short pulses are required, such as micromachining and welding, surgery, optical radar, high-speed photography, and experiments in nonlinear optics and Raman spectroscopy. M. L.

A65-12389 #

INDUCED EMISSION OF NEW INFRA-RED TRANSITIONS IN GASES
M. Pauthier (Laboratoire Central de Télécommunications, Paris, France).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964, p. 44-1 to 44-8. 20 refs.

Review of work done on gas lasers involving induced emission of infrared transitions in gases. Lifetime and pumping considerations are examined, including optical pumping. Experimental results are reviewed. The mechanisms of excitation in electron bombardment are classified in three ways: (1) direct excitation by electronic collisions, (2) excitation through collisions with auxiliary gas molecules, and (3) excitation through dissociation of molecules. Experimental results are reviewed, as well as work currently being done at L. C. T. (Paris). An analysis of the kinetics of cascade lasers is given. Characteristics of pulsed lasers are discussed. It is concluded that many new discoveries remain to be made in the field of gas lasers.

M. L.

A65-12391 #

A PORTABLE LASER RANGEFINDER.

G. W. Hamilton (Barr and Stroud, Ltd., Glasgow, Scotland).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers. London, Institution of Electrical Engineers, 1964, p. 47-1, 47-2.

Presentation of the performance characteristics of a portable laser rangefinder capable of ranging up to 10 km with an accuracy of 10 meters. A Q-switched ruby laser is used. The Q-switch arrangement is a spring-energized rotating prism capable of an equivalent rotational speed well in excess of 150,000 rpm. At maximum, 200 millijoules with a pulsewidth of 50 nanoseconds are emitted. The entire system is reported to be battery operated and to weigh approximately 35 pounds.

M. L.

A65-12392 #

GALLIUM ARSENIDE LIGHT SOURCE AND ITS APPLICATIONS.

J. C. A. Chaimowicz and W. H. Chettle (M.C.P. Electronics, Ltd., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 48-1 to 48-3.

Outline of the design, performance, and applications of an industrial infrared GaAs light emitter. The construction, light output, and electrical characteristics are discussed. The range is limited by beamspread, atmospheric absorption and scatter, and the SNR. Modulability, ruggedness, and small size are considered the outstanding advantages of the device. It is concluded that the emitter shows great promise in telecommunications and industry. Suggested applications include use in photoelectric paper tape readers, shaft encoders, and burglar alarms.

M. L.

A65-12394 #

POWER OUTPUT CHARACTERISTICS OF RUBY LASERS.

D. Haig-Arbib (G. and E. Bradley, Ltd., London, England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 50-1 to 50-4.

Analysis in practical terms of the effects caused by altering parameters which determine the operation of medium-power (5-50 joules) ruby lasers. The investigations are confined to 6-1/2" rods, 3/8" and 1/2" in diameter, with a 6-1/2"-long arc flash tube. As a result of a study of materials, it is found possible to achieve almost 90% reflectivity, together with a relatively tough surface skin layer by using anodized hyperpure aluminum. This layer appeared to stand up to the light flux without marked deterioration over several hundred firings. From thermal measurements it is established that the laser rod absorbs about 18% of the total available electrical power supplied to the flash tube when using 1/2" rods. With the 3/8" rods, only about 13% is absorbed, confirming that for good geometrical efficiency the rubies should be of a diameter at least equal to the bore of the flash tube. It is found that the rubies employed, though pumped to many times threshold, did not exhibit any of the occasionally reported features, such as turning orange, saturating, or super-radiance. Practical results are graphically presented, and it is found that the threshold level values vary with mirror reflectivity almost precisely, as predicted by theory. The very large effect of temperature on the operation threshold and on the efficiency of the ruby as an energy converter is graphically shown.

M. L.

A65-12395 #

THE GENERATION OF HIGH CURRENT PULSES OF SHORT DURATION FOR USE WITH GALLIUM ARSENIDE LAMPS AND LASERS.

F. G. Everest, P. Leggett, and E. S. Taggart (British Aircraft Corp., Ltd., Stevenage, Herts., England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 51-1 to 51-5.

Presentation of a simple solid-state circuit to pulse a GaAs laser with high current densities of short duration, fast rise time, and low duty cycles. A Shockley diode, which is a p-n-p-n junction device that passes very little current until a predetermined voltage is reached, after which it avalanches, is shown being used in several circuit diagrams. It is found that by using a Schmitt trigger circuit, 70-amp pulses at 10 kc of about 2 μ sec duration can be obtained. Running freely, so that the circuit is less than critically damped, 120-amp pulses at 10 kc are also obtainable. Defining the electrical efficiency as the ratio of the power in the discharge circuit to that delivered from the power supply, the efficiency is found to be about 60%. It is concluded that the circuit described is versatile, reliable, and electrically economical.

M. L.

A65-12396 #

DISTANCE MEASUREMENT USING LASERS.

K. Dillon Harris (G. and E. Bradley, Ltd., London, England).

IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.

Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.

London, Institution of Electrical Engineers, 1964, p. 52-1 to 52-5.

Examination of the usefulness of the laser in precise distance measurement. Three basic ways are considered in which a laser may be used as the source of energy in distance measurement: (1) by using the high coherence of the laser output to produce an interference pattern over the distance to be measured, it is possible to express the distance in terms of a number of wavelengths of

light; (2) by modulating the laser with some high-frequency radio signal, it is possible to compare the phase of modulation of the transmitted wave with that of the received wave and so calculate the distance; and (3) a pulse-modulated signal may be timed over the distance and back, so that the distance may be computed, as in conventional radar. It is concluded that these three methods of distance measurement are all capable of development into very useful instruments which have complementary ranges and accuracies. It is considered certain that distance measurement is an area where lasers will find one of their largest fields of application. M. L.

A65-12397 #**PHYSIOLOGICAL HAZARDS OF LASER RADIATION.**

M. J. Allwood (Royal Air Force, Institute of Aviation Medicine, Farnborough, Hants., England) and J. M. Flood (Royal Aircraft Establishment, Farnborough, Hants., England).
IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.
Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 53-1 to 53-5.

Calculation of safety thresholds for the amount of high-energy-density laser light the human eye can absorb. It is graphically shown that transmission through ocular media is high for the radiations from the ruby (694.3) and neodymium lasers (1060 m μ). It is found that it is absorption of incident energy by the pigment of the retina and choroid that is responsible for local tissue damage. Equations are formulated allowing for such variables as size of the iris opening, degree of pigmentation, retinal image size, and viewing conditions. It is shown that laser radiation can definitely and irreversibly damage the retina. It is strongly urged that the viewing of laser beams in any way, directly or indirectly, be avoided. M. L.

A65-12398 #**TRANSMISSION MEASUREMENTS ON A CONFOCAL LENS SYSTEM.**

M. M. Ramsay and G. I. Turner.
IN: LASERS AND THEIR APPLICATIONS; CONFERENCE, LONDON, ENGLAND, SEPTEMBER 29-OCTOBER 1, 1964.
Conference sponsored by the Electronics and Science Divisions of the Institution of Electrical Engineers, the Institute of Electrical and Electronics Engineers (United Kingdom and Eire Section), and the Institution of Electronic and Radio Engineers.
London, Institution of Electrical Engineers, 1964, p. 55-1, 55-2.

Study of the transmission performance of a confocal lens system using 6 convex and 2 planoconvex lenses. A He-Ne gas laser, operating in a simple TEM_{00q} mode at 0.6328 microns, is used as the source. A Galilean telescope is used to convert the laser output to a parallel beam of about 1-cm diam. Total transmission of the system was found to be 60%. Signal pulses of less than 5-microsec halfwidth are obtained from the laser by pulsing the 27-Mc excitation. M. L.

A65-12442**TRANSMISSION LINE FORMULATION FOR OPTICAL MASER AMPLIFICATION.**

H. Jacobs, L. Hatkin, F. A. Brand (U.S. Army, Electronics Command, Electronics Laboratories, Fort Monmouth, N. J.), and D. A. Holmes (Carnegie Institute of Technology, Pittsburgh, Pa.).
Optical Society of America, Journal, vol. 54, Dec. 1964, p. 1416-1424. 6 refs.

Treatment of the optical maser from the standpoint of distributed lines. Transmission line analogs are set up generally for a system consisting of air, reflector, active medium, reflector, and air again. It is postulated that, in the active medium, the growth of the wave can be looked upon as due to the presence of an effective ly negative conductivity. The problem is discussed for three

media - air, ruby, air - and for the five-media case: air, reflector, ruby, reflector, and air. Calculations are carried out showing that the five-layer case for special conditions can be reduced to a three-layer case. Equations for amplification and oscillation are developed which give the same results as Maiman's criteria for oscillation and Smiley's Fabry-Perot analysis for gain. The effective length of the line is estimated, and one-dimensional wave propagation is justified on the basis of the small spreading angle. Some of the more recent predictions of gain as a function of length and negative attenuation factor are explained in terms of the impedance matching of an electromagnetic wave in air to the impedance seen at the front surface of the crystal. (Author) M. M.

A65-12481 #**FREQUENCY SPLITTING AND MODE COMPETITION IN A DUAL-POLARIZATION He-Ne GAS LASER.**

Walter M. Doyle and Matthew B. White (Ford Motor Co., Philco Corp., Philco Research Laboratory, Newport Beach, Calif.).
Applied Physics Letters, vol. 5, Nov. 15, 1964, p. 193-195.

Experimental investigation of the mode splitting introduced by birefringence in a laser which operates simultaneously in two mutually perpendicular polarizations. The laser used consisted of an He-Ne discharge tube with antireflection-coated, borosilicate glass windows perpendicular to the tube axis, and spherical cavity mirrors with near confocal spacing (about 150 cm). The competition between axial modes for a range of splittings up to 3 Mc was studied by stressing the laser windows. Within this range, the polarization characteristics of the laser were unchanged, and, even for the smallest observable splittings (1 Kc/sec), no breakdown of the dual polarization behavior was observed. It is pointed out that it would seem that the observed effects are the result of birefringence, induced either by residual stresses in the dielectric reflectors or by the action of a magnetic field on the active medium (Voigt effect). The gain saturation effects discussed by Tang and Statz may also be effective in enhancing the stability of the dual polarization behavior. M. M.

A65-12483 #**INTERNAL FREQUENCY MODULATION OF GaAs JUNCTION LASERS BY CHANGING THE INDEX OF REFRACTION THROUGH ELECTRON INJECTION.**

G. E. Fenner (General Electric Co., Research Laboratory, Schenectady, N. Y.).
Applied Physics Letters, vol. 5, Nov. 15, 1964, p. 198, 199. 5 refs.

Experimental investigation of the possibility of changing the resonance frequency of a particular mode by changing the index of refraction of a laser. This is done by the injection of electrons into the path traversed by the electromagnetic waves. It is stated that, in diode lasers, one can visualize a system of two electrically separated diodes which are coupled optically to form a common cavity. One diode acts as generator of the coherent oscillations, while the other serves as "modulator." In order to bypass some of the difficulties of alignment, as well as to match the optical properties at the common boundaries between the diodes, a particular approach was chosen, which is sketched in a figure. It is stated that, from the practical point of view, it now appears feasible to frequency modulate injection lasers simply and efficiently with a larger modulation index than so far has been possible with any other laser system. M. M.

A65-12484 #**CROSS-PUMPED Cr³⁺-Nd³⁺:YAG LASER SYSTEM.**

Z. J. Kiss and R. C. Duncan (Radio Corporation of America, RCA Laboratories, Princeton, N. J.).

Applied Physics Letters, vol. 5, Nov. 15, 1964, p. 200-202.

Research sponsored by the Radio Corporation of America; Contract No. AF 33(615)-1096.

Experimental investigation of energy transfer from the third bands of Cr³⁺ to the 4f states of Nd³⁺ in yttrium aluminum garnet.

This doubly doped system has been operated as a cross-pumped cw laser. It is stated that both spectroscopic and threshold measurements indicate that, for equal crystal qualities, the $\text{Nd}^{3+}:\text{Cr}^{3+}:\text{YAG}$, through cross-pumping, should provide, by a factor of at least two, greater efficiency or lower threshold in cw laser operation than the self-pumped $\text{Nd}^{3+}:\text{YAG}$ laser. Yttrium aluminum garnet is an excellent host in which to incorporate the rare earth and Cr^{3+} , at the yttrium and aluminum sites, respectively. The excitation spectrum of a doubly doped nominal 1% Cr^{3+} + 1.3% $\text{Nd}^{3+}:\text{YAG}$ is shown, together with the absorption spectrum of the straight Cr^{3+} -doped crystal. It is shown that there is efficient pumping of the Nd^{3+} fluorescence in the Cr^{3+} absorption bands.

M. M.

A65-12485 #**FM OSCILLATION OF THE He-Ne LASER.**

S. E. Harris (Stanford University, Dept. of Electrical Engineering, Stanford, Calif.) and Russell Targ (Sylvania Electric Products, Inc., Sylvania Electronic System Div., Electronic Defense Laboratories, Mountain View, Calif.).

Applied Physics Letters, vol. 5, Nov. 15, 1964, p. 202-204. 7 refs.

Contract No. AF 33(615)-1938.

Description of the operation of a He-Ne laser in a manner such that all of the laser modes oscillate with FM phases and nearly Bessel function amplitudes, thereby comprising the sidebands of a frequency-modulated signal. It is stated that the resulting laser oscillation frequency is, in effect, swept over the entire Doppler linewidth at a sweep frequency which is approximately that of the axial mode spacing. This type of FM oscillation is induced by an intracavity phase perturbation which is driven at a frequency which is approximately, but not exactly, the axial mode spacing. The experimental evidence supporting the hypothesis of an essentially pure FM oscillation is indicated.

M. M.

A65-12486 #**FM LASER OSCILLATION - THEORY.**

S. E. Harris and O. P. McDuff (Stanford University, Dept. of Electrical Engineering, Stanford, Calif.).

Applied Physics Letters, vol. 5, Nov. 15, 1964, p. 205, 206. 9 refs.

Contract No. AF 33(657)-11144.

Presentation of a first-order theory of the FM oscillation of the He-Ne laser recently demonstrated by Harris and Targ. The bases of the calculation are the self-consistency equations of Lamb. The solution is said to be an FM signal whose modulation depth is an infinitely growing function of time. The existence of this unstable on-frequency solution has been previously noted by Yariv. It is pointed out that the important contribution of the paper is the existence of the steady-state off-frequency FM solution. Though the present analysis neglects the question of saturation, it appears to explain many of the observations of Harris and Targ. The results are said to be in excellent agreement with those of an experiment recently performed by Targ.

M. M.

A65-12488 #**FINITE PULSE-TIME EFFECTS IN THE FLASH DIFFUSIVITY TECHNIQUE.**

R. E. Taylor (North American Aviation, Inc., Atomics International Div., Canoga Park, Calif.) and J. A. Cape (North American Aviation, Inc., Science Center, Thousand Oaks, Calif.).

Applied Physics Letters, vol. 5, Nov. 15, 1964, p. 212, 213. NASA-supported research.

Experimental verification of the accuracy of the pulse calculation for the ruby laser source. The test was performed using Armeo iron, which is the generally accepted thermal conductivity standard. The results are shown in a figure. It is stated that, by using an approximate facsimile of the actual pulse shape, the experimental values are brought into close agreement with the accepted values for Armeo iron.

M. M.

A65-12621**MEASUREMENT OF A PLASMA DENSITY BY MEANS OF A GAS LASER [MESURE DE LA DENSITE D'UN PLASMA PAR UN LASER A GAZ].**

Claude Gormezano (Commissariat à l'Énergie Atomique, Centre d'Études Nucléaires de Saclay, Service de Physique Appliquée, Gif-sur-Yvette, Seine-et-Oise, France).

Académie des Sciences (Paris), Comptes Rendus, vol. 259, no. 17, Oct. 28, 1964, p. 2805-2808. 5 refs. In French.

Description of the measurement of the electronic density of a plasma created by azimuthal compression, by means of an interferometer whose source is a gas laser (Ne-He). The measurement method is said to be simple, reliable, inexpensive, and exempt from the uncertainties connected with measurements by means of a Langmuir probe used in a dense and pulsed plasma.

M. M.

A65-12626 #**OPERATION OF A GASEOUS XENON-KRYPTON LASER [O RABOTE GAZOVOGO LAZERA NA SMESI KSENON-KRIPTON].**

D. I. Mash, V. F. Papulovskii, and L. P. Chirina.

Optika i Spektroskopiia, vol. 17, Nov. 1964, p. 796-798. 5 refs. In Russian.

Experimental investigation of a xenon-krypton laser emission in twelve wavelengths ranging from 2.03 to 9μ . Emission in wavelengths up to 3.5μ is obtained by a laser with external mirrors. Longwave laser emissions in wavelengths less than 3.11μ are obtained, using silver coated mirrors. Emissions in 3.28, 3.37, and 3.5μ lines are obtained, using a silver-coated mirror and a mirror coated with a multi-layer dielectric. Finally, laser emissions at wavelengths over 3.5μ are obtained, using inner confocal mirrors. Data on xenon and krypton emission wavelengths are tabulated. In addition, diagrams are included, showing: (1) energy levels of xenon and krypton, (2) the relationship between the output power and pressure of the gas mixture ($\lambda = 3.508\mu$ Xe), (3) the relationship between the output power and pressure of the gas mixture ($\lambda = 2.52\mu$ Kr), and (4) the relationship between the power and pressure of the gas mixture at various pumping levels ($\lambda = 2.19\mu$ Kr).

J. R.

A65-12748 #**OPTIMUM COMPOSITION OF THE He AND Ne MIXTURE IN A LASER.**

W. Woliński, T. Adamowicz, M. Nowicki, and A. Kaźmirowski (Warszawa, Politechnika, Katedra Przyrządów Elektronowych, Warsaw, Poland).

Académie Polonaise des Sciences, Bulletin, Série des Sciences Techniques, vol. 12, no. 7, 1964, p. 541-546.

Investigation of the influence of partial and total pressure changes in helium and neon gas mixtures on the magnitude of the output power of a gas laser. The maximum output power of the laser considered - operating with 250 watts of excitation power - was obtained with a neon partial pressure of 0.055 torr and a total pressure of 0.44 torr. The experiments reportedly showed that for a CW He/Ne laser, excited by an HF field, an optimum filling of the tube may be determined in terms of the laser radiation. The results, however, are said to relate to a laser with a certain known geometry of tube and electrodes and with particular power and frequency from the exciting generator. The vacuum stand employed was composed of a rotary pump, a set of diffusion pumps, and two titanium pumps. Hot-cathode ion gages and a resistance gage were used, and baking was accomplished by means of an electric furnace.

D. H.

A65-13007 #**THEORY OF LASERS OPERATING UNDER STORAGE CONDITIONS.**

A. L. Mikaelian and Iu. G. Turkov.

Radiotekhnika i Elektronika, vol. 9, Apr. 1964.)

Radio Engineering and Electronic Physics, vol. 9, April 1964, p. 601-604. Translation.

Discussion of the principles of operation of an idealized two-level laser system with controlled Q, with particular emphasis on pulse length and switching rate. It is shown that, if the Q of the laser at the instant of emission considerably exceeds the threshold level, the pulse length will depend only slightly on the switching rate; and, if the threshold level is only insignificantly exceeded, the dependence on the switching rate becomes strong. In case of slow switching of Q, the emission will consist of a sequence of individual pulses.

J. R.

A65-13008 #**A POSSIBLE MECHANISM OF RADIATION BEATS IN A LASER.**

A. V. Uspenskii.

(Radiotekhnika i Elektronika, vol. 9, Apr. 1964.)*Radio Engineering and Electronic Physics*, vol. 9, April 1964, p. 605-607, 5 refs. Translation.

Investigation of the characteristics of a steady-state pulsating regime of a laser in which, under certain conditions, undamped beats (pulsations) arise. A mechanism for these beats is proposed, which involves fluctuations of the phase difference between the polarization of the material and the field. A two-level system $E_2 > E_1$ is considered.

J. R.

A65-13170**ACCURATE LENGTH MEASUREMENT OF METER BAR WITH HELIUM-NEON LASER.**

K. D. Mielenz, H. D. Cook, K. E. Gilliland, and R. B. Stephens (National Bureau of Standards, Washington, D.C.).

Science, vol. 146, Dec. 25, 1964, p. 1672, 1673.

Use of a helium-neon gas laser in conjunction with an automatic fringe-counting interferometer (line-scale comparator) to measure the length of a standard meter. From the fringe counts and the internationally accepted value for the mercury-198 line at 4360 Å, the wavelength of the employed laser was obtained as 6328.1983 Å under standard metrological conditions (air at 20°C, standard atmospheric pressure, 59% relative humidity, and 0.03% CO₂ content). With respect to the assigned length of the bar, the agreement in the obtained measurements was 7 parts in 100 million.

W. M. R.

A65-13323 #**ATOMIC IODINE PHOTODISSOCIATION LASER.**

Jerome V. V. Kasper and George C. Pimentel (California, University, Chemistry Dept., Berkeley, Calif.).

Applied Physics Letters, vol. 5, Dec. 1, 1964, p. 231-233, 8 refs. Grant No. AF AFOSR-332-63.

Description of laser action observed at 1.30 μ (7700 cm⁻¹) during flash photolysis of both gaseous CF₃I and gaseous CH₃I. The emission is due to the ²P_{1/2} - ²P_{3/2} transition of atomic iodine at 1.315 μ, and is the first laser in which inversion is achieved through photodissociation. The results indicate both an attractive new mode of laser excitation, and a new method of analyzing the energy distribution among chemical species produced through the rupture of chemical bonds.

P. K.

A65-13472**MOVING STRIATIONS IN A He-Ne LASER.**

A. Garscadden, P. Bletzinger (USAF, Office of Aerospace Research, Aerospace Research Laboratories, Wright-Patterson AFB, Ohio), and E. M. Friar (USAF, Systems Command, Research and Technology Div., Electronics Research Branch, Wright-Patterson AFB, Ohio).

Journal of Applied Physics, vol. 35, Dec. 1964, p. 3432, 3433, 9 refs.

USAF-supported research.

Observation of the dependence of moving striation frequencies on the discharge current in a dc gas laser. A mutual influence of moving striations and laser action is also reported.

(Author) W. M. R.

A65-13475**MODE-SELECTING PRISM REFLECTORS FOR OPTICAL MASERS.**

J. A. Giordmaine and W. Kaiser (Bell Telephone Laboratories, Inc., Murray Hill, N.J.).

Journal of Applied Physics, vol. 35, Dec. 1964, p. 3446-3451, 17 refs.

Description of a prism reflector possessing high reflectivity for only a very narrow angular range (~1'). The prism makes use of multiple internal reflections near the critical angle, where the dependence of reflectivity on angle is extremely sharp. It is shown experimentally that such a prism can be used to suppress unwanted off-axis modes in an optical maser. With a typical ruby optical maser, a substantial reduction in beam width, as well as an increase in emission near the beam center, is observed. Applications to various optical masers and use as a modulator are discussed.

(Author) W. M. R.

A65-13493**ANGULAR DISTRIBUTION OF RADIATION FROM GaAs INJECTION LASERS.**

Marvin M. Antonoff (Sperry Rand Corp., Sperry Rand Research Center, Sudbury, Mass.).

Journal of Applied Physics, vol. 35, Dec. 1964, p. 3623, 3624, 10 refs.

Calculation of the angular distribution of radiation from a gallium arsenide injection laser in the plane normal to the junction plane. The electromagnetic modes of the active slab are used as sources of the emitted field so that comparison of the computational results with experimental data can provide a test of the dielectric slab model. Despite the considerable differences that may exist between theory and actual devices, it is concluded that the predictions of the dielectric slab model are in line with observed patterns. It is seen that a more rigorous comparison must await improved techniques for fabricating more nearly planar junctions.

W. M. R.

A65-13494**PERFORMANCE OF THE PLASMA THETA-PINCH FOR LASER PUMPING.**

S. Aisenberg, D. V. Missio, and P. A. Silberg (Raytheon Co., Waltham, Mass.).

Journal of Applied Physics, vol. 35, Dec. 1964, p. 3625, 3626.

Preliminary study of some characteristics of theta pinches for improved optical pumping of laser crystals. Of particular interest were: (1) the relative light output as a function of capacitor voltage, and (2) the energy coupling efficiency for conversion of stored energy to plasma energy for various gases and pressures. Laser output was observed for a CaWO₄(Nd³⁺) dielectric-coated crystal. A typical output consisted of about eight fairly regular spikes in about 20 μsec. There was a delay of about 10 μsec before laser action began. For the gases investigated, argon and krypton, a predominantly line spectrum was obtained.

W. M. R.

A65-13501**THERMAL LIMITATIONS ON THE ENERGY OF A SINGLE INJECTION LASER LIGHT PULSE.**

G. J. Lasher (International Business Machines Corp., Research Div., Solid State Science Dept., Yorktown Heights, N.Y.) and W. V. Smith (International Business Machines Corp., Research Div., Physical Science Dept., Yorktown Heights, N.Y.).

IBM Journal of Research and Development, vol. 8, Nov. 1964, p. 532-538.

Contract No. DA-30-069-ORD-3542.

Estimation of the upper limits on the output pulse power of an injection laser arising from heating effects. The heat is assumed to be dissipated by conduction through a large homogeneous body. A simple method for computing overall diode efficiency is given.

(Author) W. M. R.

A65-13503**HIGH POWER CW OPERATION OF GaAs INJECTION LASERS AT 77°K.**

J. C. Marinace (International Business Machines Corp., Research Div., Yorktown Heights, N. Y.).
IBM Journal of Research and Development, vol. 8, Nov. 1964, p. 543, 544. 9 refs.

Report of the continuous-wave operation at 8400 Å of unsilvered gallium arsenide lasers at 77°K and power levels near 0.65 watt, and description of the heat sink that afforded the necessary thermal transfer characteristics. The plates for the heat sink mouth were fashioned from ordinary Cu or Mo annealed stock that is not of exceptionally high purity; thicknesses of 0.020 and 0.025 in. were used. After fabrication, the free ends of the metal plates were electroplated with about 15 microns of In. There was no heating of the assembled device subsequent to the mounting of the laser, as is usually done to bond the laser to its contacts, since it has been found that heating is detrimental to performance and does not appreciably decrease the series electrical resistance. The good thermal transfer between the laser and the mount is believed to be due, at least in part, to the metallurgical simplicity of the system. W. M. R.

A65-13600

THE ANOMALOUS LIGHT DISPERSION IN R-LINES OF RUBY AND REFRACTION SHIFT IN THE SPECTRUM OF A LASER [ANOMAL'NAIA DISPERSIYA SVETA V R-LINIYAKH RUBINA I REFRAKTSIONNOE SMESHCHENIE SPEKTRA GENERATSII OPTICHESKOGO KVANTOVOGO GENERATORA].

I. S. Gorban' and G. L. Kononchuk.

Optika i Spektroskopiya, vol. 17, Dec. 1964, p. 880-886. 8 refs. In Russian.

Experimental measurement of the light dispersion caused by chromium in the region of R-lines of ruby at room temperature and at temperature of liquid oxygen. It is found that the dispersion curves obtained can be approximated by formulas with a set of parameters related to the unity of chromium concentration. These expressions can be used to calculate the curve of light dispersion in R-lines of ruby in the case of two main polarizations and an arbitrary chromium concentration. The phenomenon of refraction shift in the spectrum of a laser is also considered. J. R.

A65-13603

OPTICAL LASER ON A MIXTURE Xe AND He FOR $\lambda = 3.50 \mu$ [OPTICHESKII KVANTOVYI GENERATOR NA SMESI Xe I He DLIA $\lambda = 3.50 \text{ MK}$].

E. P. Markin and V. V. Nikitin.

Optika i Spektroskopiya, vol. 17, Dec. 1964, p. 953, 954. In Russian.

Investigation of the relationship between the output power of a laser operating on a Xe-He mixture at a wavelength of 3.50 μ and the diameter of the discharge tube, gas mixture pressure, pumping capacity, and duration of the discharge in order to determine the optimum conditions assuring maximum output. The results obtained are graphically illustrated. It is found that the laser output grows linearly with the duration of the discharge. J. R.

A65-13630

POSSIBILITIES OF OPTICAL COMMUNICATIONS.

W. A. Gambling (Southampton, University, Southampton, England).
Engineering, vol. 198, Dec. 18, 1964, p. 776, 777.

Discussion of the sending of information by means of light beams. Basic principles of communication are reviewed, the main factors to be considered being (1) the channel bandwidth B which is proportional to the operating frequency, (2) the loss of power along the transmission path, and (3) the noise level at the receiver. A brief discussion of the possibilities of the laser beam demonstrates its capability to convey a very large amount of information in a very short time. It is shown that lasers are attractive for interplanetary communications, since they require small transmitting systems which can easily be carried by satellites, or could perhaps be operated from the Moon. The practical possibilities of high-capacity light

guide systems for long distance terrestrial optical communication are briefly examined. Problems of noise in light signals, and the arrangement of transmitter and receiver circuits are discussed. Speculation is made concerning future applications. F. R. L.

A65-13697

NEW LASER TRANSITIONS IN IODINE - INERT GAS MIXTURES.

R. C. Jensen and G. R. Fowles (Utah, University, Dept. of Physics, Salt Lake City, Utah).

IEEE, Proceedings, vol. 52, Nov. 1964, p. 1350.

NSF-USAF-supported research.

Observation of 11 new laser transitions in mixtures of iodine and helium. With six previously reported oscillations, this brings the total to 17. All of these wavelengths lie between 4986 Å and 1.06 μ ; as yet, no effort has been made to extend the investigations beyond these extremes. Twelve of the lines have been tentatively identified as belonging to the spectrum of singly ionized iodine. Of these, all except the 5625-Å line originate on one of three 6p' levels of ionized iodine. These levels lie within 0.5 eV of the 24.58-eV ionization energy of helium. Thus, it appears that population enhancement of the levels is achieved through a resonant ion-atom exchange collision involving ionized helium and ground-state iodine atoms. The lines at 5625 and 6904 Å oscillated when the helium was replaced with neon. Oscillation on the 6904-Å line was obtained with a low-pressure (≈ 0.1 torr) mixture of iodine and krypton. No laser action was obtained on any of the reported lines using argon or xenon. W. M. R.

A65-13698

DUAL POLARIZATION FM LASER COMMUNICATIONS.

Walter M. Doyle and Matthew B. White (Philco Corp., Research Laboratory, Newport Beach, Calif.).

IEEE, Proceedings, vol. 52, Nov. 1964, p. 1353.

General description of the operating principles and output capabilities of an FM laser communication system under development that would utilize a plasma tube with antireflection-coated windows oriented perpendicular to the tube axis and an electro-optic component such as a Kerr cell or Pockels cell. Since the subcarrier frequency is to be produced by beats between laser modes of opposite polarization, it will have an upper bound determined by the greatest separation at which the two modes can oscillate simultaneously. This separation is in turn determined by the Doppler width of the laser transition (approximately 900 Mc for the 1.15- μ He-Ne line). Conversely, the lower bound is determined by the smallest separation that can be established for mutually perpendicular modes before competition for atoms causes one or the other mode to dominate. This separation would be expected to be comparable in magnitude to the natural line width of the atomic transition (about 70 Mc). It has been found, however, that axial-mode separations of less than 27 Mc can be attained, and, presumably because of spatial dissimilarities of their intensity distributions, nonaxial modes separated in frequency by less than 1 kc can be made to oscillate at the same time. W. M. R.

A65-13699

SOME OBSERVATIONS ON TRIANGULAR GaAs LASERS.

I. Ladany (U.S. Naval Research Laboratory, Washington, D. C.).

IEEE, Proceedings, vol. 52, Nov. 1964, p. 1353, 1354.

Observed behavior of 20 equilateral-triangle, gallium arsenide lasers with substrate doping (3×10^{18} Te), zinc diffusant, contacts of essentially indium and tin dots, and excitation by 1- or 2- μ sec pulses in liquid nitrogen. Some of the units showed the characteristic beams at a 120° angle, attributed to the Fabry-Perot-type mode, although the typical Fabry-Perot spectrum could not be demonstrated. Most gave no beam, but, rather, an isotropic light distribution, or, sometimes, very faint lines (on an image converter); such spectra were identified with the internal mode. The thresholds of the units (10,000 amp/cm² for the beam types, and slightly less than 7000 amp/cm² for the internal types) were consistent with the thresholds for Garfinkel's isosceles right-triangular lasers, though higher by a factor of 10. W. M. R.

A65-13700**ROOM-TEMPERATURE GaAs LASER VOICE-COMMUNICATION SYSTEM.**

D. Karlsons, C. W. Reno, and W. J. Hannan (Radio Corporation of America, RCA Laboratories, Camden, N. J.).

IEEE, Proceedings, vol. 52, Nov. 1964, p. 1354, 1355.

Operating characteristics of a voice communication system using a gallium arsenide injection laser at room temperature. The feasibility of this device is seen to be the direct consequences of the development of specially grown low-threshold room-temperature GaAs laser diodes recently reported. The system uses pulse frequency modulation at a 20-kc average repetition rate and has a 6-kc-wide voice channel.

W. M. R.

A65-13702**GAS LASERS IN MAGNETIC FIELDS.**

S. A. Ahmed, R. C. Kocher, and H. J. Gerritsen (Radio Corporation of America, RCA Astro Electronics Div., David Sarnoff Research Center, Princeton, N. J.).

IEEE, Proceedings, vol. 52, Nov. 1964, p. 1356, 1357.

Effects of axial and transverse magnetic fields on the power output of a helium-neon laser operating in the high-gain 3.39- μ transition. The laser tube investigated was a 1-m quartz tube (8-mm ID) filled with a 0.5-torr He, 0.1-torr Ne gas mixture and terminated in plane quartz windows perpendicular to the axis. Brewster windows were arranged in mounts insertable between the tube and the mirrors. Pumping was by 60-Mc RF. The variation of laser output was measured with and without Brewster windows for several pumping levels. In an axial field, the output decreased, eventually to extinction at about 2000 gauss. In a transverse field, the output first dipped slightly, then increased to remain constant to magnetic fields in excess of 2000 gauss. These output variations are attributed to Zeeman splitting and the effect of the Brewster windows, and to plasma effects.

W. M. R.

A65-13703**STABILITY AND AMPLITUDE-MODULATION CHARACTERISTIC OF THE DISCHARGE CURRENT, IN A DC-PUMPED, HELIUM-NEON GAS LASER TUBE.**

Viktor Met (Watkins-Johnson Co., Palo Alto, Calif.).

IEEE, Proceedings, vol. 52, Nov. 1964, p. 1357, 1358.

Observation of large-signal oscillatory instabilities in a variety of high-gain, dc-pumped, gas laser tubes, in the frequency range from 150 to 600 kc where stability is normally expected. Usually, the disturbances grow exponentially and, within a few microseconds, extinguish the discharge. Over a critical range, the $v(i)$ characteristic functions as a limiter, producing sustained sinusoidal oscillations superposed on the static discharge current I_0 , of amplitudes up to one-third of I_0 . An equivalent circuit is produced to explain the observations.

W. M. R.

A65-13705**SELECTION OF DISCRETE MODES IN TOROIDAL LASERS.**

D. Roess and G. Gehrler (Siemens und Halske Aktiengesellschaft, Zentral-Laboratorium, Munich, West Germany).

IEEE, Proceedings, vol. 52, Nov. 1964, p. 1359, 1360. 11 refs.

Observation of laser oscillations in ruby cubes and rings with highly polished surfaces. The relaxation behavior of these totally reflecting resonators is assumed to be the result of the simultaneous excitation of a great number of modes of a similarly high Q. Mode selection was introduced into a toroidal ruby resonator through a scar in the outer cylinder surface. The scar suppressed modes reflected in its area; the mode selection could be varied by the depth of the scar. Very flat scars below 50- μ depth led to no observable variation of the frequency spectrum or of the time dependence of the emission. With a scar of 130- μ depth the spectrum was sharpened with two distinct maxima in the Fabry-Perot fringes. At the same time the emission changed in its time dependence: sharp spikes of regular succession alternated with periods of quasi-continuous emission. With a scar of 150- μ depth in a ruby ring of only 0.006% Cr³⁺, discrete modes could be selected at room temperature. The fringes then consisted of sharp lines of widths equal to the instrument's resolution. The emission was concentrated

in isolated, periodical, sharp spikes, each exhibiting a periodical amplitude modulation, the origin of which is not yet clear.

W. M. R.

A65-13706**HIGH-EFFICIENCY INJECTION LASER AT ROOM TEMPERATURE.**

H. Nelson, J. I. Pankove, F. Hawrylo, G. C. Dousmanis (Radio Corporation of America, RCA Laboratories, Princeton, N. J.), and C. Reno (Radio Corporation of America, RCA Defense Electronics Products, Camden, N. J.).

IEEE, Proceedings, vol. 52, Nov. 1964, p. 1360, 1361. 5 refs.

Operating characteristics of a room-temperature laser diode fabricated by the epitaxial growth of an n-type GaAs layer on a Zn-doped GaAs substrate. The junction was somewhat broadened by a subsequent diffusion treatment. Ohmic electrodes were sintered onto both sides of the wafer which was then cleaved and cut to form small parallelepipeds. The laser had two cleaved (110) facets 9 mils apart and roughly cut sides 5 mils apart, and it was soldered between two massive Cu bars. The drive was by either a 1.1- μ sec pulse generator operating at 60 pulses/sec and capable of delivering 30 amp with a rise time of about 50 nsec or by a 20-nsec pulser having a 1-nsec rise time and capable of delivering flat-topped pulses of up to 36 amp at 120 pulses/sec.

W. M. R.

A65-13711**THE MINIMUM SPOT SIZE FOR A FOCUSED LASER AND THE UNCERTAINTY RELATION.**

P. W. Carlin (Colorado, University, Dept. of Electrical Engineering, Boulder, Colo.).

IEEE, Proceedings, vol. 52, Nov. 1964, p. 1371.

Use of the Heisenberg uncertainty principle to establish the lower bound for the width of the energy distribution of a focused laser (or other) beam from an optical device. The derived spot size, $(1/\pi)(L/d)\lambda$, is seen to be fairly close to the null-to-null diameter of the ordinary circular diffraction pattern, which is $(3.83/\pi)(L/d)\lambda$. The target distance at which the average energy density must be less than that at the lens is $L > \pi d^2/\lambda$. For a 10-in. lens and light from a ruby laser, this occurs beyond 280 km.

W. M. R.

A65-13867 #**MOLECULAR-HYDROGEN LASER PULSE GENERATION [IMPUL'SNAIA GENERATSIIA LAZERA NA MOLEKULIARNOM VODORODE].**

P. A. Bazhulin, I. N. Kniazev, and G. G. Petrash (Akademiia Nauk SSSR, Fizicheskii Institut, Moscow, USSR).

Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki, vol. 47, Oct. 1964, p. 1590, 1591. In Russian.

Observation of a pulse-generated laser with a plasma resulting from a discharge in hydrogen as the medium. The setup used and the process of laser generation are described. A plausible theory is proposed to explain the mechanism of spectrum line inversion which is found to take place in the experiments.

V. Z.

A65-13871 #**QUANTUM PARAMAGNETIC AMPLIFIERS [KVANTOVYE PARAMAGNITNYE USILITELI].**

V. B. Shteinshleiger and S. V. Dedkov.

Radiotekhnika, vol. 19, Nov. 1964, p. 5-18. 66 refs. In Russian.

Survey of the current status of maser amplifiers, on the basis of information published in the US over the period 1962-1963. Trends in the development of maser amplifiers are outlined, starting from techniques developed to extend the transmission band of resonator devices and TW masers, over masers operating in the millimeter-wave range, to the improvement of maser noise characteristics by the use of superconducting magnets and closed-cycle cooling systems. A 70-Gc TW maser built by the Westinghouse Electric Corp., and several advanced masers developed by the Microwave Electronic Corp., the Bell Telephone Laboratories, Inc., and other establishments are described. Some maser applications in radar tracking are examined.

V. P.

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