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TECHNOLOGY UTILIZATION

OPTICS AND LASERS

A COMPILATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Foreword

The National Aeronautics and Space Administration has established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace community. By encouraging multiple application of the results of its research and development, NASA earns for the public an increased return on the investment in aerospace research and development programs.

This document is one in a series intended to furnish such technological information. Divided into three sections, this Compilation presents a number of innovative devices and techniques in optics and related fields. Section 1 covers advances in laser and holography technology. Section 2 contains several articles on spectroscopy and general optics, and Section 3 includes new information in the area of photography.

Additional technical information on the innovations described herein can be requested by circling the appropriate number on the Reader Service Card included in this Compilation.

The latest patent information available at the final preparation of this Compilation is presented on the page following the last article in the text. For those innovations on which NASA has decided not to apply for a patent, a Patent Statement is not included. Potential users of items described herein should consult the cognizant organization for updated patent information at that time.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this Compilation.

Technology Utilization Office
National Aeronautics and Space Administration

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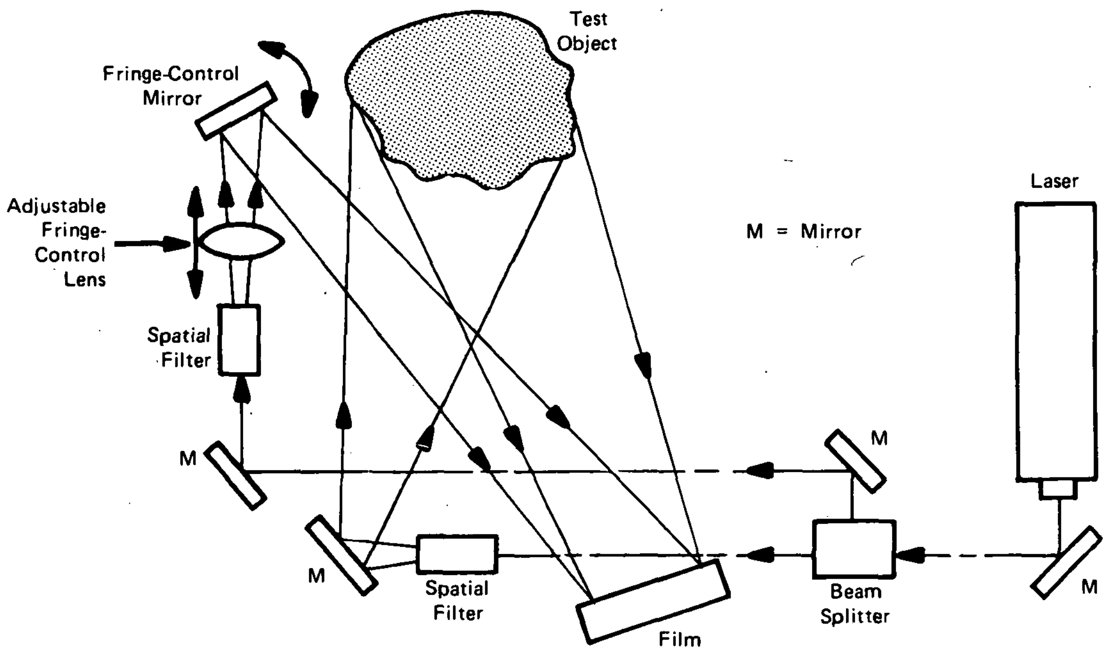
Contents

Section 1. Laser Technology

REFERENCE-BEAM CONTROL OF HOLOGRAPHIC INTERFEROMETRY FRINGE PATTERNS



Laser-Beam Fringe-Control System

Fringe-pattern for a holographic interferometer is usually attained by manipulation of the illumination beam. In a new technique, the reference beam is used to regulate the fringe, by means of mirrors and adjustable lenses.

The figure shows a typical table setup utilizing the reference beam for fringe control. The fringe-control mirror is used to position the bull's-eye in the fringe pattern, and the fringe-control lens is adjusted to control the width of the fringes. The adjustments can be made without affecting the critical-illumination setting made in the object beam. Improved and more rapid adjustment is possible, because interaction is eliminated from the object beam.

Source: F. H. Stuckenberg of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-17788)

No further documentation is available.

BROADBAND MODULATION-INDEX METER

An automatic metering system supplies a real-time indication of the modulation index associated with laser beams. The technique is shown in the block diagram (Figure 1). The input for the meter is the signal from the anode of a photomultiplier tube. The dc and video-channel amplifiers separate and amplify the ac and dc components. The video signal is applied to the sampling gate, which is opened by short pulses from the pulse generator. The repetition rate of the sampling pulses is determined by the voltage-controlled multivibrator, with its frequency controlled by the integrated low-frequency multivibrator output. The sample amplifier amplifies the short-term, sample-and-hold output of the sampling gate.

The positive and negative peak levels of the split signal are derived separately by the two peak detectors. A difference amplifier compares the two peak levels and generates a bias feedback, which is used to keep the sampling bridge balanced. The peak-to-peak value of the video signal is derived at the output of the sum amplifier, which adds the outputs of the peak detectors. This signal is inverted and is applied to one input of the analog divider. The other input is from the dc channel amplifier.

The output of the dc-channel amplifier is a voltage proportional to the output power of the laser; this output is also used to drive a meter and/or a recorder. The output of the analog divider is a voltage proportional to the modulation index; it also drives a meter and/or a recorder.

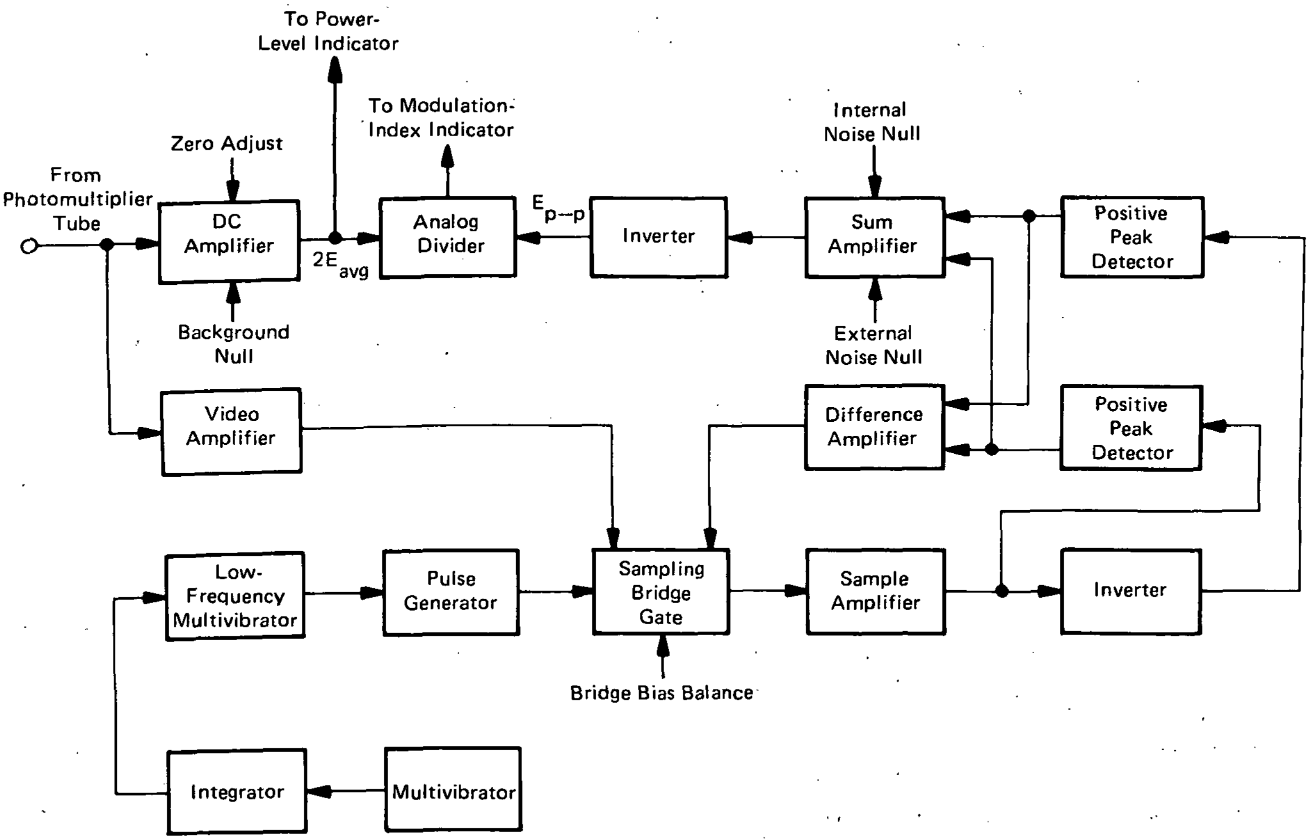


Figure 1. System Block Diagram

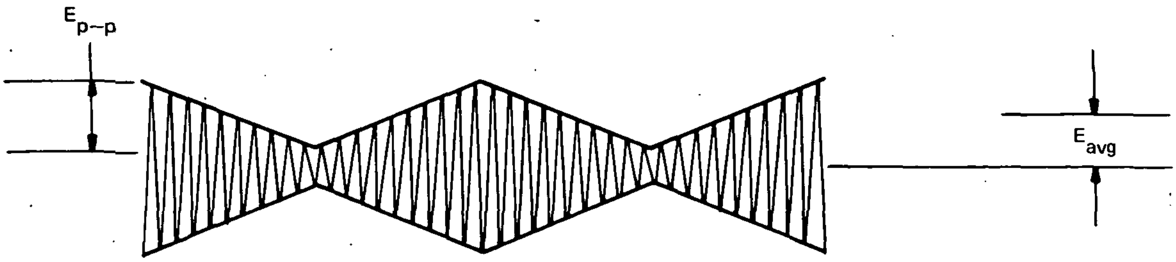


Figure 2. Amplitude Modulation

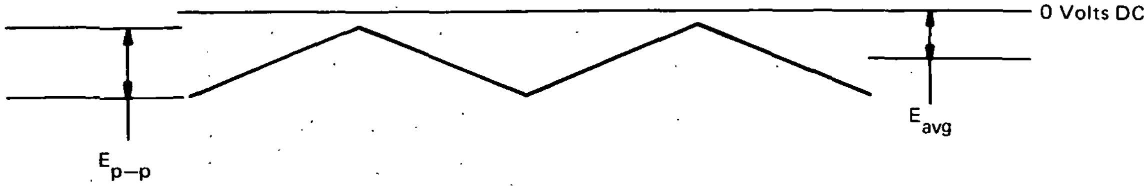


Figure 3. Demodulated Signal

Figure 2 illustrates an amplitude-modulated signal. The modulation index (m) can be found from the relationship: $m = E_{p-p}/2E_{avg}$. Figure 3 shows the detected signal at the photomultiplier anode. This is the input to the system, from which the modulation index is computed. The index meter allows unattended, real-time measurements for a wide range of modulation frequencies and for wide variations in signal-power levels.

Source: G. B. Shelton and W. A. Hurd of Sperry Rand Corp. under contract to Marshall Space Flight Center (MFS-22740)

Circle 1 on Reader Service Card.

MEASUREMENT OF RELATIVE DEPTH IN HOLOGRAPHIC IMAGES

A double reference beam can be used to create a double holographic image, from which relative depth may be determined by taking measurements between the identical points of the twin images. When the hologram is illuminated with light from two separate sources, with a known angle between the sources and one known distance in the recorded holographic image, it is possible to determine the distance of other points geometrically, once their lateral translation is known. This method, as illustrated in Figure 1, is more accurate than conventional stereoptic techniques.

The double image is recorded on a film plate, and the depth analysis is made as described in Figures 2 and 3. Two initial reference points such as 1 and 2 are chosen (1′ and 2′ are the same points in the second image). If these points are chosen so that the relative depth (ΔL) of each is known, then a quantitative ratio may be found for calculating other depth as follows: Distances D_1 and D_2 (Figure 2) are measured on the film. For a small angle α in a triange with side a opposite α and the two other sides $b \cong c$,

$$b \cong \frac{a}{2} \csc \frac{\alpha}{2}$$

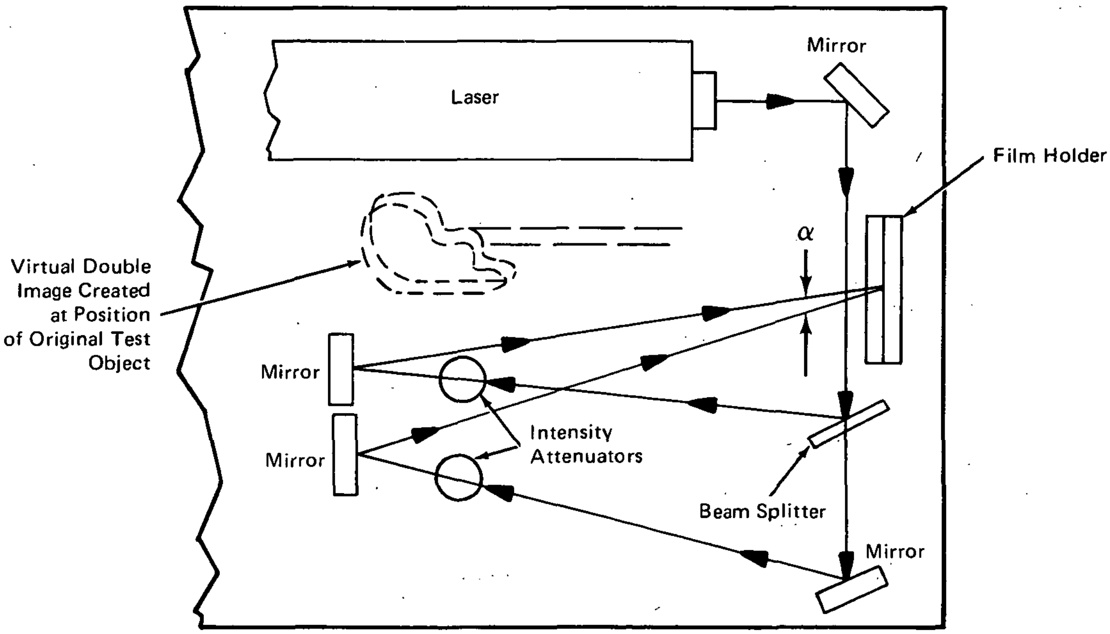


Figure 1. Double Reference Illumination

In Figure 3, L_1 corresponds to b and a corresponds to the distance between spatial points 1 and 1′, which is proportional to D_1 on the film. Thus, when this proportionality constant is known, the ΔL for any point may be calculated from measurements on the film. The proportionality constant may be found from a known ΔL as follows:

$$L_1 \propto \frac{D_1}{2} \csc\frac{\alpha}{2}; \text{ and likewise}$$

$$L_2 \propto \frac{D_2}{2} \csc\frac{\alpha}{2}; \text{ and}$$

$$(L_1 - L_2) = \Delta L_{12} \propto \frac{1}{2}(D_1 - D_2) \csc\frac{\alpha}{2}, \text{ or}$$

$$\Delta L_{1\text{-}2} \cong C\,(D_1 - D_2), \text{ where C is a constant.}$$

Since ΔL_{12} is known, C may be calculated, and the relative depth of other points may be found from lateral measurements on the film plate.

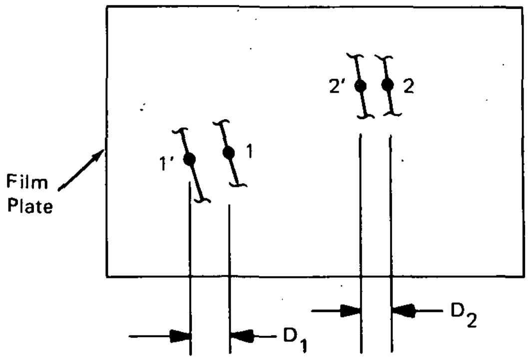


Figure 2. Measurement of Offset of Typical Points on Double Virtual Image on the Film

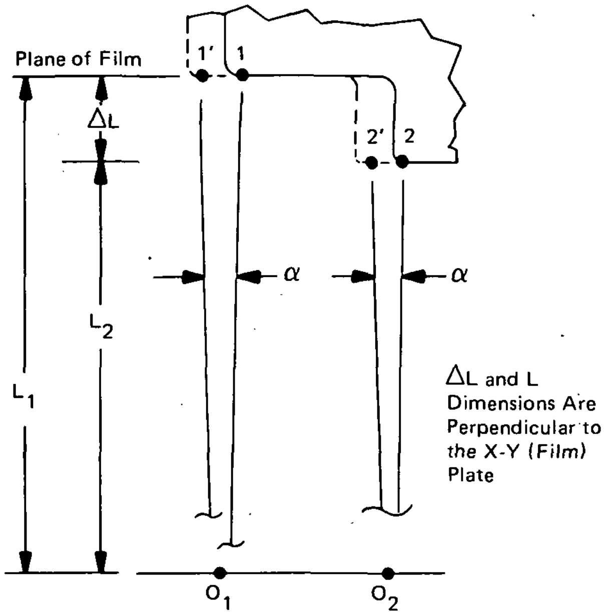


Figure 3. Spatial Relationship Showing How ΔL Varies With Offset of Double Images

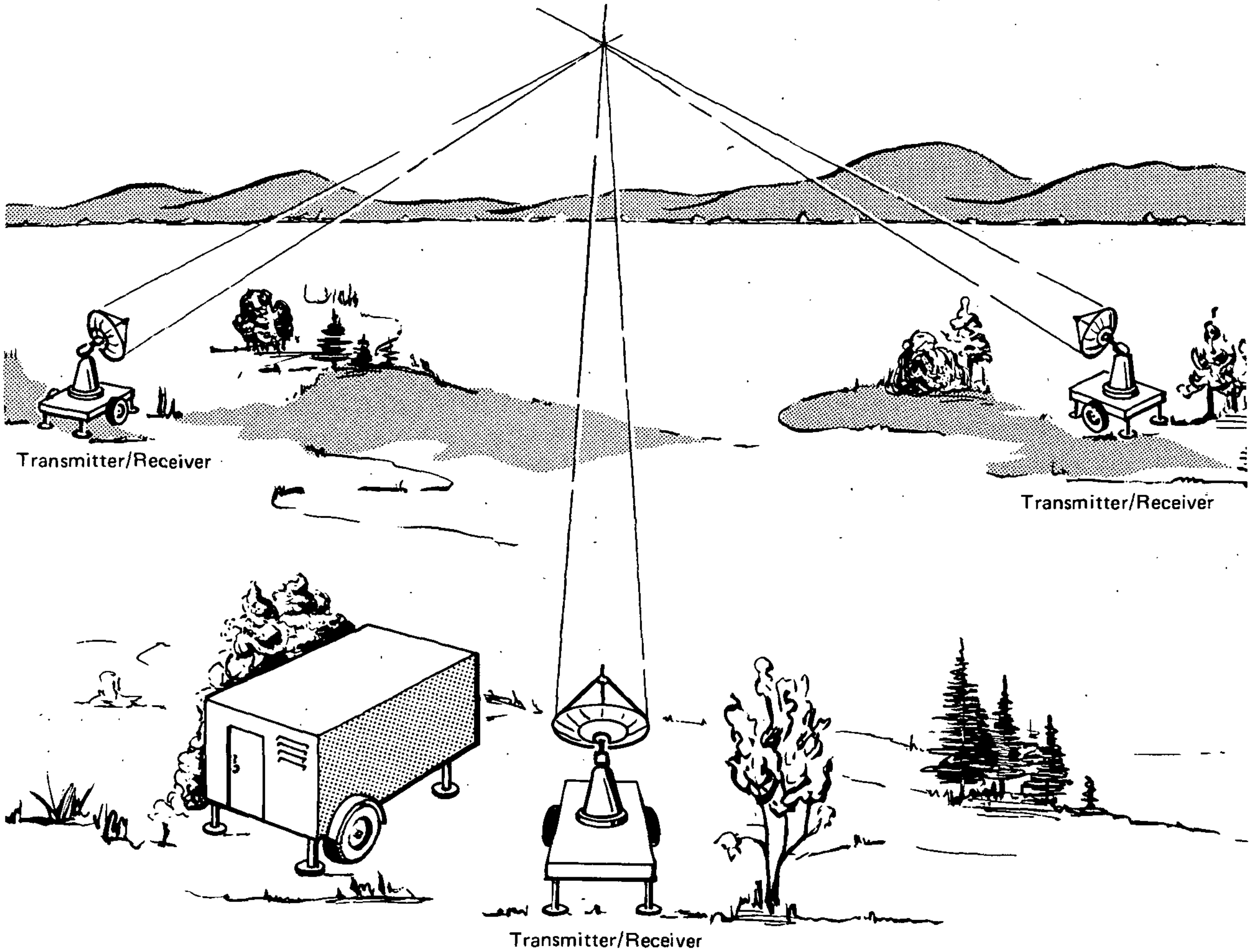
If no reference ΔL is known, a series of offset measurements, D_1, D_2, D_3, ..., may be made. From these, relative depth ΔL may be established from ratios such as:

$$\frac{\Delta L_{12}}{\Delta L_{23}} = \frac{D_1 - D_2}{D_2 - D_3}$$

Source: F. H. Stuckenberg of Rockwell International Corp. under contract to Johnson Space Center (MSC-17632)

No further documentation is available.

DEVELOPMENT OF A THREE-DIMENSIONAL LASER-DOPPLER SYSTEM



3-D Coaxial System (A bistatic system would have a separate transmitter and receiver at each station, thus requiring three additional components.)

A report is available on a system for measuring atmospheric-wind velocity and aircraft-trailing vortices, using a three-dimensional laser-doppler system. Three-dimensional measurements are an advance over the one-dimensional coaxial heterodyne system, that lacks the specified resolution characteristics. Several such systems are described and evaluated in the report.

A system using a CO_2 laser as the source of illumination measures the doppler shift of illuminated moving objects. The scattering targets are the aerosols, contained in the atmosphere, that are excited and then are relaxed to atmospheric velocity. This scattered energy is collected, heterodyned (combined with a portion of the incident radiation), and detected. The frequency of the detector output signal gives a measure of a component of the atmospheric velocity.

Another method described is fringe anemometry, in which a laser generates a fringe pattern in the atmosphere. Aerosols travel through the pattern and scatter an intensity-modulated signal. An analysis of the intensity modulation gives a measurement of the transverse wind velocity.

Doppler systems (see figure) are constructed in a coaxial configuration with common transmitting and receiving optics as opposed to bistatic systems that use a separate transmitter and a separate receiver. Another approach, using radar wavelengths to obtain three velocity components from a single system by a conical scan, has also been evaluated.

The evaluation of these and other systems indicates that the best methods are (A) electronic beam-sharpening coaxial heterodyne system and (B) the bistatic heterodyne system. The only drawback in A is the possibility of a velocity error in certain rare circumstances. In system B, there are problems with signal/noise ratios, alignment, scanning, cavity isolation, and probability of detection. When the two systems are compared, spatial resolution and velocity accuracy are better in B but angular alignment is worse. The signal/noise ratios are similar for both. Average detection probability and false-alarm rate are 96.5 percent and 10^{-6}, respectively, for A, while in B the detection probability is a function of the misalignment between the transmitter and the receiver. Also, there is a lag-angle problem with scanning in A.

The report includes design details on the laser, the interferometer, the frequency translator, telescope, output mirror, and detector. There is also a block diagram of the equipment and the computer system.

Source: F. Campbell, W. Keene,
A. Jelalian, and C. Sonnenschein of
Raytheon Company
under contract to
Marshall Space Flight Center
(MFS-22669)

Circle 2 on Reader Service Card.

DOUBLE FILM-PLATE HOLOGRAPHY

Time and cost may be reduced with a new technique for obtaining high-quality double-exposure holograms that record real-time visual displays of interferometric fringe patterns. A commercial double-width film-plate holder is used to hold two film plates. Guides or pins may be added to permit precise removal and replacement of either plate. The two film plates are placed emultion-to-emulsion in the holder for the initial exposure. This forms a basic hologram of the illuminated test object in each film plate. Both exposed plates are then removed, and the front plate is developed. The back plate is stored in a light-tight container for later double exposure.

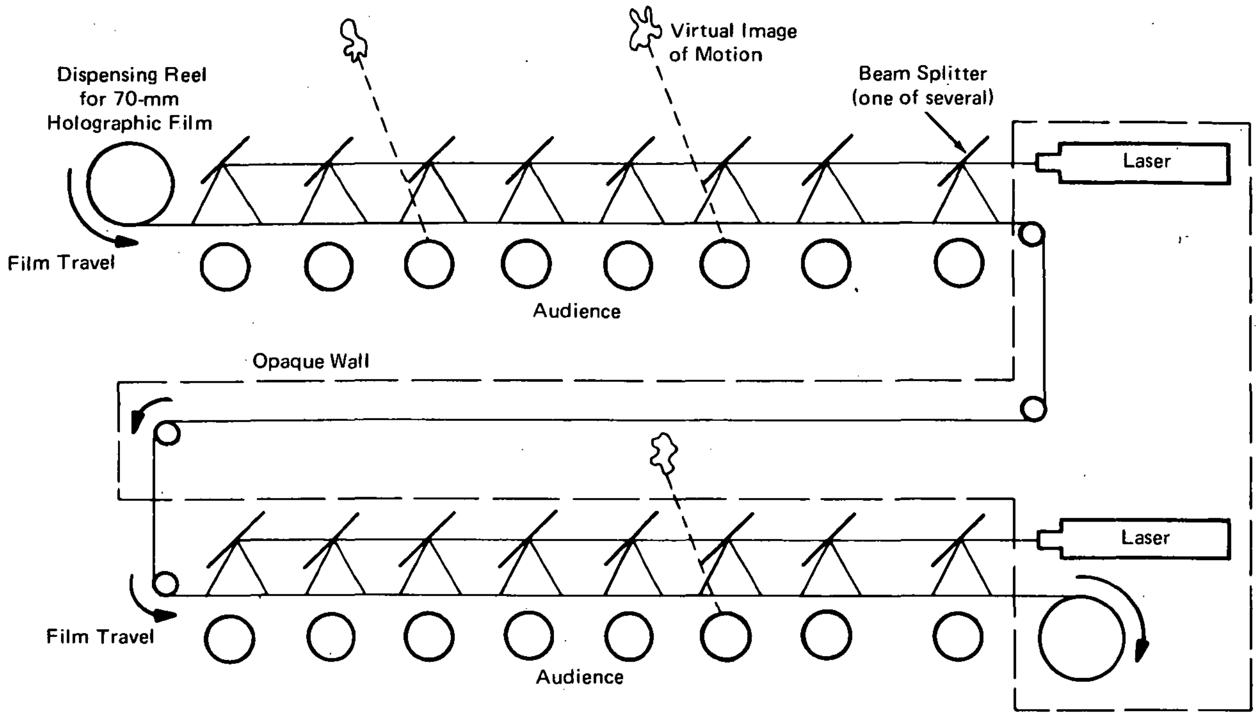
Next, a clear plate (without emulsion) is placed back on the developed hologram, and the assembly is reloaded into the holder. The test object is stressed, and the fringe pattern is observed through the clear back plate, or with a television monitor. The laser is adjusted to provide the optimum fringe patterns needed to investigate the strain distribution. Following this, the clear back plate is replaced, in darkness, by the undeveloped hologram. The two holograms must be matched exactly to their original positions. This unchanged stressed setup is used to make a double exposure of the fringe pattern in the back plate. The added fringe pattern is recorded in exact relation to the original hologram.

After removal of the test setup, the developed double exposure can be laser illuminated while being held in a single holder. The resulting holographic projection displays the test object with the fringe pattern showing on its surface.

Source: F. H. Stuckenberg of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-17787)

No further documentation is available.

A HOLOGRAPHIC VIEWING SYSTEM FOR LARGE AUDIENCES



Multiple-Viewing System

For the first time, it is possible for a very large audience to view simultaneously a three-dimensional holographic motion picture. The virtual image of a 70-mm filmstrip is used without either the limitations of the film size or the use of a two-dimensional screen. Because a hologram is reconstructed by reproducing the incidence of the reference beam at the same angle at which the hologram was made, many such beams must be supplied for multiple viewers.

The illustration shows how several lasers and m beam splitters (B/S) are used to allow multiple viewers. The actual size of the audience determines how many beam splitters must be used. The 70-mm filmstrip is allowed to pass in front of each viewer and then on to the next one, until it is finally rewound on a takeup spool or returned to the original reel. Each viewer in his own viewing section can see five to seven separate holograms from the total movie at one time. Each hologram on the filmstrip measures about 70 by 70 mm; they are recorded successively on the entire length of the filmstrip at the rate of 20 to 30 exposures per second. This is necessary in order to allow the reconstruction of real-time motion.

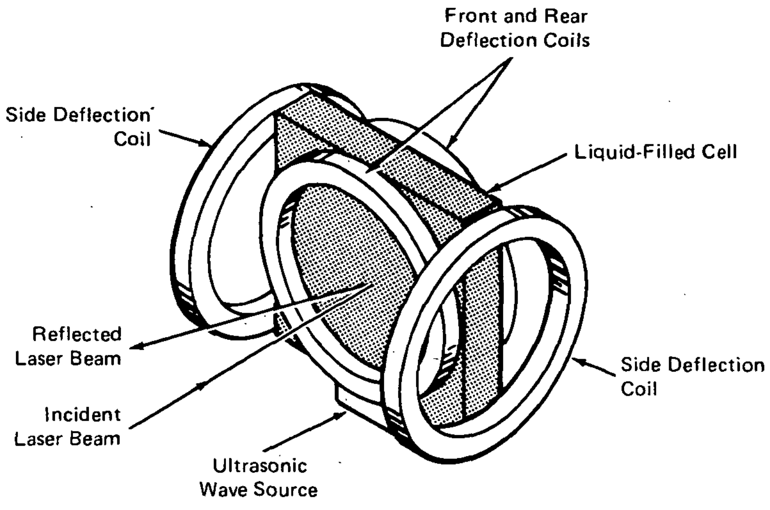
In a very large audience, the last observer sees a given scene considerably after the first observer saw that scene, due to the travel speed of the filmstrip. The sound has to be synchronized with the passage of the frames past the respective viewing section. This method allows the size of the effective hologram to be as large as desired, simply by displaying the long filmstrip in front of the viewers, rather than having the viewers look through a single section separately as has been done up to now; the size of the hologram per se limits the audience size.

The filmstrip may be displayed above or in front of the viewer or reflected by spherical mirrors to become enlarged. In any case, the observer must look through several frames of the film at once. As the entire strip passes by, the viewer receives the total information present in the holographic filmstrip. This new technique will be useful in visual instruction and communications, although the necessity of audio synchronization for the individual viewer limits its use for entertainment purposes.

Source: R. L. Kurtz
Marshall Space Flight Center
(MFS-22723)

Circle 3 on Reader Service Card.

LASER BEAM DEFLECTION CONTROL: A CONCEPT



Laser Deflection Device

Improved control of laser beam deflection angles may result from a new conceptual device. Reflectively coated magnetized particles are suspended in a liquid-filled cell surrounded by two pairs of crossed electromagnetic coils and are selectively aligned by controlling the magnetic fields.

The cell contains a low-viscosity fluid to minimize frictional losses, and low-inertia particles to permit rapid deflection of the incident beam. Each particle consists of a magnetized core located normally to the reflective surface. This assures particle alignment in a uniform direction when a magnetic field is applied. An ultrasonic energy source keeps the particles suspended in the fluid.

One process for making the particle is to chemically deposit a thin layer of silver on a flat base, deposit a magnetized powder in the presence of a normal magnetic field, and deposit another layer of silver. The base is then dissolved and the sandwich plate broken to the desired particle size.

This concept should be of interest to designers and manufacturers of electro-optical devices, systems and support equipment. It has potential applications in laser TV and display systems, optical signal processing and optical memories.

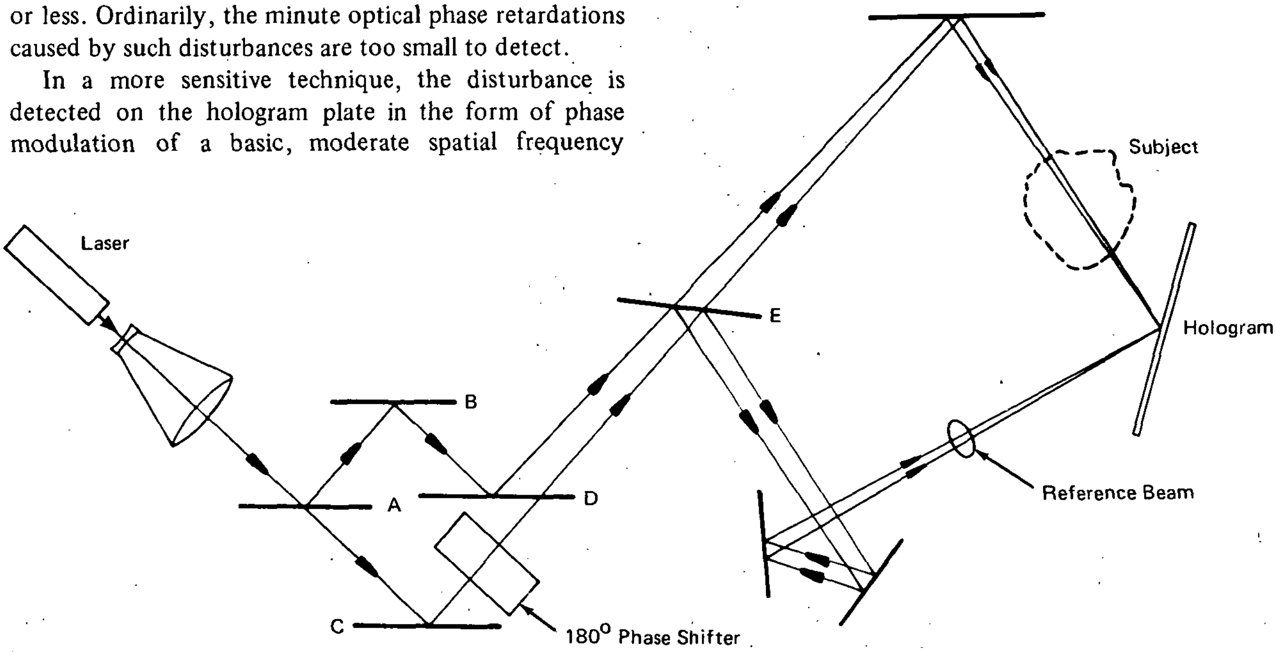
Source: C. L. Garvie of
Lockheed Electronics Co.
under contract to
Johnson Space Center
(MSC-13814)

No further documentation is available.

SENSITIVE HOLOGRAPHIC DETECTION OF SMALL AERODYNAMIC PERTURBATIONS

A method has been developed to enhance the sensitivity of holographic techniques for detecting the very small aerodynamic disturbances which are caused by variations in gas density of the order of 1/10 wavelength or less. Ordinarily, the minute optical phase retardations caused by such disturbances are too small to detect.

In a more sensitive technique, the disturbance is detected on the hologram plate in the form of phase modulation of a basic, moderate spatial frequency grating; the first exposure is made of the unperturbed gas, and the second of the gas in the perturbed state. Since the system responds only to changes in the subject between exposures, perfect optics are not required. The readout resembles that from a double exposure, subfringe, holographic interferogram. The subject perturbations show up as brightenings on a dark background.



Optical Diagram for Phase-Modulation Hologram

To produce the phase modulations, the subject and reference beams in the holographic apparatus are each separated into two component beams. The angle between the components is small and is the same for both the subject and the reference beams. As shown in the figure, mirrors A, B, C, and D form two beams at a small angle; beamsplitter E divides these into subject and reference beam pairs.

In the first exposure, the two components of the subject beam interfere with each other at the hologram, producing effectively a single wave with an amplitude that varies sinusoidally as the hologram is traversed; the same is true for the reference wave. The interference between the subject and reference beams thus has an intensity which varies like a $\sin^2$ function for the relatively slow variations corresponding to the fringes produced by the narrow angle between components. Superimposed on these slow variations are the fine holographic fringes corresponding to the large angle between the subject and reference beams.

For the second exposure, a phase shift of 180° is introduced into one component of the subject beam and the corresponding component in the reference beam. The phase shift causes a displacement of the slow variation of the intensity at the hologram so that the intensity varies like a $\cos^2$ function; the fine fringe, holographic component is not changed. In view of the fact that $\sin^2+\cos^2 = 1$, the sum of the two envelope intensities is constant. Thus, a hologram produced in the absence of a change in the subject is simply a uniform grating of fine fringes which diffracts only a plane wave upon reconstruction. However, if the object introduces a small differential phase shift between the two exposures, the phase (position) of the fine fringes for the second exposure with the $\cos^2$ envelope will be shifted accordingly. Upon reconstruction, the output wave, instead of being plane, will have a small phase wrinkle on it with the amplitude of the phase wrinkle set by the small phase shift caused by the subject. This phase wrinkle diffracts light at the small angle from the primary reconstruction, and the intensity of this diffracted light reveals the magnitude of the original, small optical perturbation made by the subject.

Source: Lee O. Heflinger of
TRW Systems Group, TRW, Inc.
under contract to
Ames Research Center
(ARC-10422)

No further documentation is available.

THREE-DIMENSIONAL GAS TURBULENCE MEASUREMENT WITH A LASER-DOPPLER VELOCIMETER SYSTEM

Conventional gas-velocity measurement devices, such as a Pitot tube or a hot-wire anemometer, are limited in dynamic range and sensitivity to velocity direction. In addition, they require a physical probe which in many cases disturbs the flow field. In contrast, the laser-Doppler system records gas-velocity data over a wide dynamic range in three-dimensional space without a physical probe.

The system detects the Doppler-frequency shift in a laser beam scattered by flowing particles and uses this frequency to calculate the particle velocities. The technique is based on the principle that a laser beam scattered by flowing particles is shifted in frequency by an amount proportional to the laser frequency. The velocities of the particles cause this shift and from the geometrical angle at which the scattered light is observed.

In use, a focused laser beam is directed into a flow field containing submicron particles. A laser-Doppler velocimeter (LDV), placed on the opposite side of the flow field, collects the forward-scattered laser light from three different directions and homodynes this light with reference, or unscattered laser light, to produce a Doppler-frequency output on three photodetectors. The three Doppler frequencies are then fed into a frequency-tracking unit which locks onto and tracks the Doppler signal. The frequency trackers provide a dc voltage output, corresponding to the mean Doppler frequency or flow velocity, and an ac voltage output, corresponding to the fluctuating Doppler frequency or flow turbulence. The three dc components are then passed through an analog network which transforms the components into three outputs, corresponding to a Cartesian coordinate system.

With a knowledge of the frequency-tracker calibration curves and the geometry of the LDV relative to the flow field, the three-dimensional levels of the particles causing the shift can be computed.

Source: C. E. Fuller of
Remtech, Inc.
under contract to
Marshall Space Flight Center
(MFS-22713)

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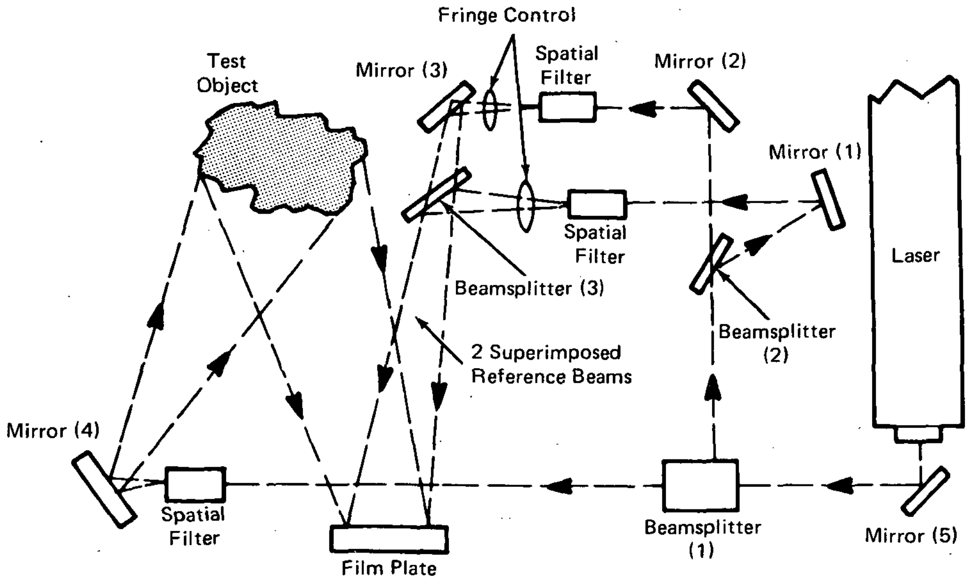
HOLOGRAPHIC TESTING WITH A DOUBLE REFERENCE BEAM



THE FOLLOWING BEAM LENGTHS ARE EQUAL

1. Beamsplitter (1) → Mirror (4) → Test Object → Film Plate
2. Beamsplitter (1) → Beamsplitter (2) → Mirror (1) → Beamsplitter (3) → Film Plate
3. Beamsplitter (1) → Mirror (2) → Mirror (3) → Film Plate

Holograms are images made on a photographic plate by the interference patterns of laser beams. They can be three-dimensional images and are used in areas as diverse as magazine covers and optical memory devices for computers. One industrial application involves "taking a picture" of a mechanical object, placing the object under stress, and taking another "double-exposure-picture" of the same object. This results in a pattern of lines around the stressed object called interferometric fringes which may be analyzed to discover the presence of flaws in the tested object. Unfortunately, this technique, as usually done, results in multiple images which interfere with analysis of the fringe pattern.

Multiple images in the object focal plane can be eliminated by the use of two reference beams instead of the usual one.

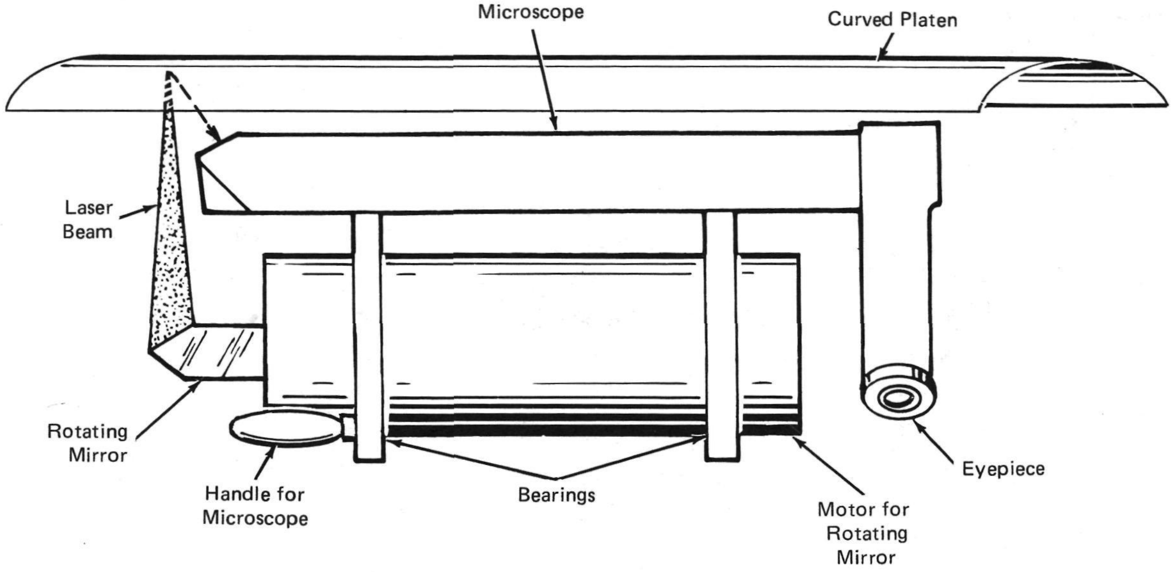
A hologram requires two beams; one is reflected off the test object to be "photographed", and the other, the reference beam, intersects the beam reflected from the test object to provide an interference pattern of light waves on the photographic plate. The image may be reconstituted by placing the plate in its original position with respect to the reference beam and illuminating it with light from the reference beam.

The figure shows how two superimposed reference beams are used to make a double exposure hologram. An image of the unstressed object is taken with the reflected beam and one of the reference beams. The object is then stressed, and a second (double) exposure is made. The developed film plate provides a double exposure hologram that can be projected by simultaneous illumination with both of the reference beams. Because the two reference beams may be adjusted separately, the appearance of multiple images may be eliminated while manipulating the fringe patterns. This is not possible in a single reference beam system.

Source: F. H. Stuckenberg of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-17959)

No further documentation is available.

ALIGNMENT MICROSCOPE FOR ROTATING LASER SCANNER



In rotary laser scanners, the alignment of the scan line relative to the points of interest on the film being scanned has been observed by one of the two methods. The first method, subject to translation errors, requires location of a film area outside the scanner. This area is then positioned in the scanner by use of an arbitrary reference point chosen on the film which will still remain outside the scanner. In the second technique, the scan line is observed at an angle through the rear of the glass platen. This method introduces distortions and makes the film backlighting somewhat difficult.

An alignment microscope assembly has been developed which allows observation of the exact position of the scan line relative to the points of interest on the film being scanned. This assembly does not interfere with the system operation.

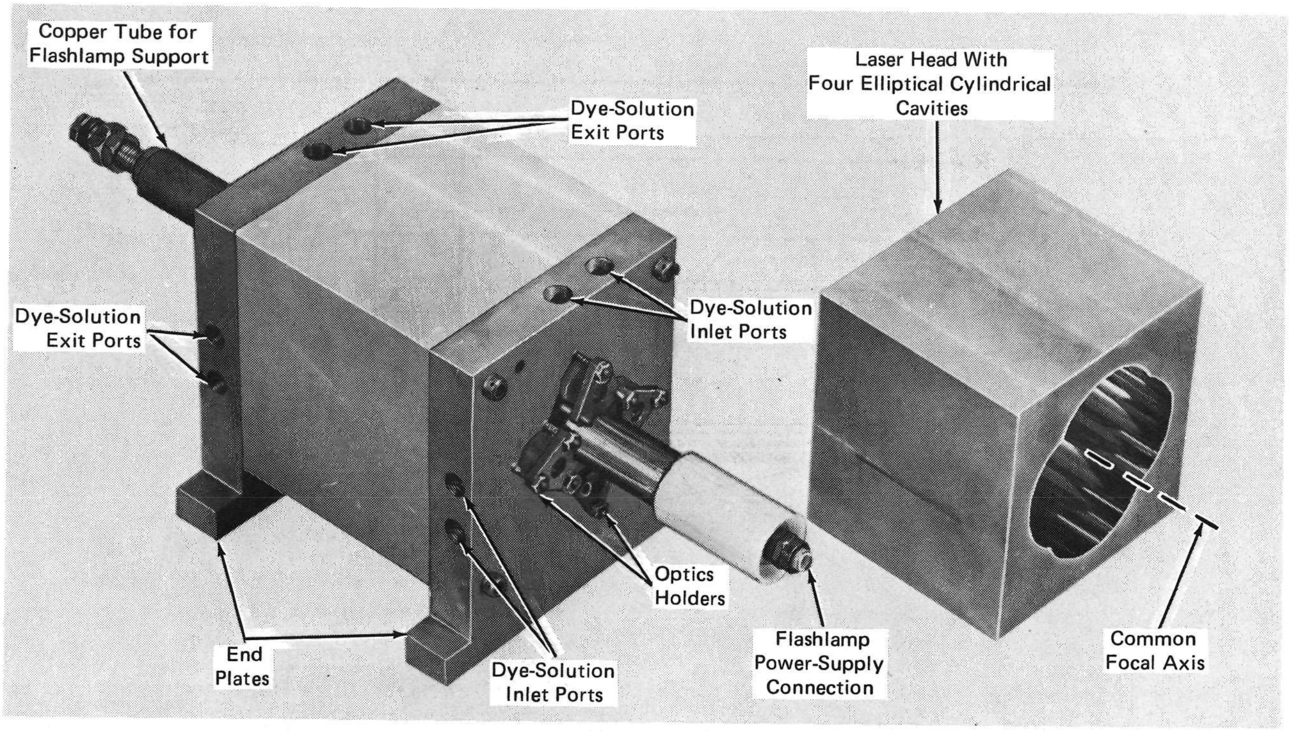
The microscope assembly, as shown in the figure, is optically designed to focus on a small area of the film along the laser scan line at an oblique angle, without significant keystoning effects. By suitable choice of angle and location of the optical components clear of the laser focusing cone, alignment of the laser scan line on the film is observed with the system in full operation. Under these conditions, the laser-beam line becomes the X-coordinate reticle. A single horizontal reticle line is included in the microscope to facilitate the Y-coordinate position indexing.

The entire assembly may be rotated about the centerline of the laser-scanner mirror which is coincident with the center of the radius of curvature of the film. The focusing eyepiece is placed in close proximity to the rotational axis of the assembly to minimize head translation during viewing of the full 72° scanned arc. In addition, a scale and index mark affixed to the rotating mirror support and microscope carrier, respectively, serve as a coarse viewing position locator. Variable backlighting of the film, accomplished in another assembly (not shown), further facilitates the microscope assembly.

Source: A. Maciel, Jr., and J. C. Beck of
Singer Link Division of
Singer-General Precision, Inc.
under contract to
Johnson Space Center
(MSC-14118)

Circle 5 on Reader Service Card.

A LASER HEAD FOR SIMULTANEOUS OPTICAL PUMPING OF SEVERAL DYE LASERS



Laser Head for Simultaneous Optical Pumping of Several Dye Lasers

A multielliptical-cavity laser head has been developed which provides simultaneous optical pumping of several dye lasers in a compact, efficient, and reliable manner. This device accomplishes such optical pumping using a single flashlamp and an electrical driver. This is possible because dye lasers require relatively low energy to operate (low-threshold pumping requirement) and provide a new simple method for producing simultaneous independent laser output at a number of different wavelengths.

In this design (see illustration), the lamp is placed on the common focal axis, and the dye cells occupy the four remaining focal axes. The dye cells share the radiation output of the lamp equally.

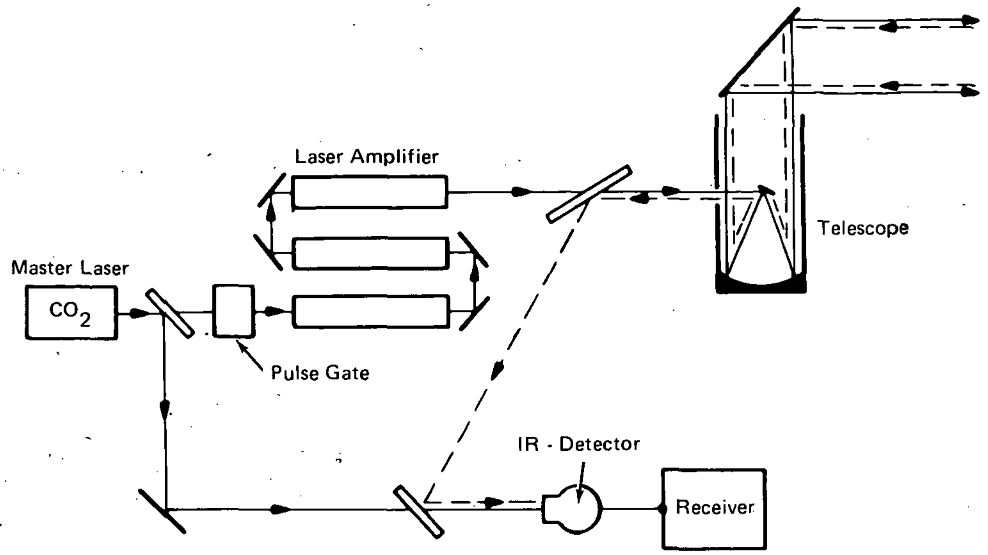
This laser head consists of a number of elliptical cylinders with a common focal axis and the remaining axes equally spaced about it. The number of cylinders used can range from one to more than eight, depending on the number of laser systems to be pumped, the available flashlamp energy, and the dye-laser medium used.

The multielliptical-cylinder cavity can be machined from a single block or made in sections and assembled. The cavity must be polished for maximum uniform reflectivity. The dye cells and the lamp are held in place by stainless steel end plates, which hold mirrors for each laser cavity, permit dye solution to flow through the cells, and reflect light from polished surfaces to increase pumping efficiency. Stainless steel is used as it is nonreactive to solvents used with the dyes. Copper tubes, mounted on the end plates, act mechanically to support the flashlamp and complete the electrical circuit as ground return. Optics holders, also mounted on the end plates, are used to support and adjust the laser mirrors. Windows are used instead of mirrors, if externally mounted mirrors are required. A standard capacitive electrical driver system is used to supply electrical energy to the flashlamp. The lamp used in this device is water cooled and rated at 100 joules input.

Source: Peter B. Mumola and
Belton T. McAlexander
Langley Research Center
(LAR-11341)

Circle 6 on Reader Service Card.

LASER SYSTEM DETECTS AIR TURBULENCE



Laser-Doppler System

A prototype laser-Doppler system can remotely measure atmospheric wind velocity and detect air turbulence. The system employs a laser beam that is emitted from a pod on the side of the aircraft. The beam is aimed ahead of the aircraft. All along its path the beam is scattered by airborne particles (e.g., dust, water droplets, ice crystals, smog, etc.). Some of this scattered light returns to the aircraft, but at a shifted frequency caused by the Doppler effect from local air speeds.

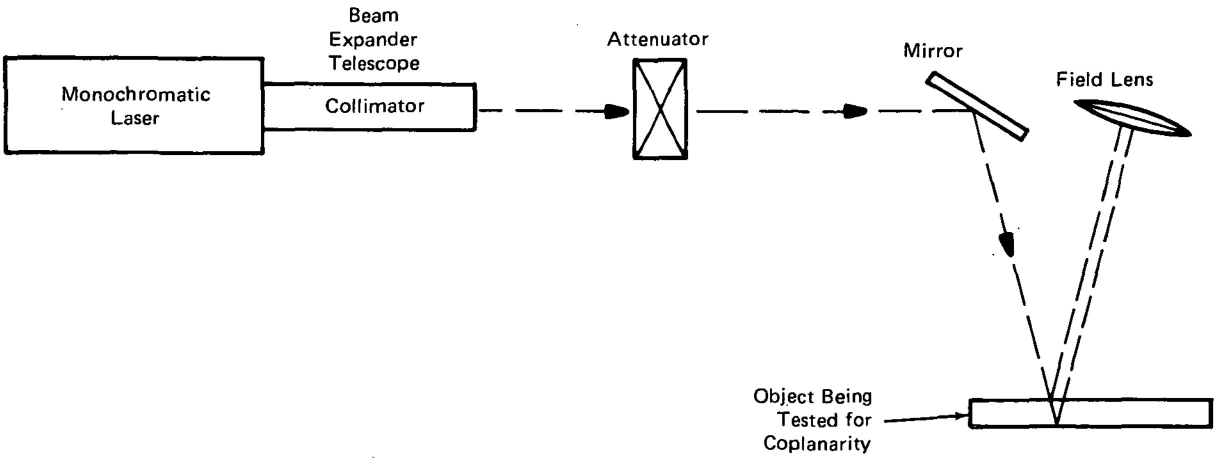
A beam from the CO_2 master laser (see figure) is split into two parts. One part is pulsed and laser amplified to increase the range and is aimed by a telescope. The second part serves as a reference beam The scattered and frequency-shifted light is recombined with the reference beam causing a beat frequency in the detector. This signal is processed in the receiver and displayed for on-board evaluation.

The system can detect a change in air velocity indicating the presence of a wind shear up to about 9 nautical miles (16.67 kilometers) ahead. Current work focuses on extending this range, including investigations of the effects of particle density, focusing, back scatter efficiency, absorption, and other factors.

Source: W. K. Dahm, J. A. Dunkin, and E. A. Weaver
Marshall Space Flight Center
(MFS-21244)

Circle 7 on Reader Service Card.

COPLANARITY MEASUREMENT TOOL



With a new technique, the plane parallelism of the opposite surfaces of transparent objects can be measured precisely. A laser-beam generator produces a beam of monochromatic light. The beam is collimated by an appropriate beam-expanding telescope and is focused on a front-surface mirror through an attenuator, which may be a neutral density filter (see figure). The reflected beam is directed from the mirror to the material being tested for uniformity of thickness, plane parallelism, or coplanarity. A reflection of the beam from the near and far surfaces of the material being tested is viewed by an observer through a field lens.

The interference patterns, produced by representative deviations from the conditions of plane parallelism, are observed as they are produced; and no adjustment of the equipment is required once it is set up.

Source: A. R. Johnston
NASA Pasadena Office
(NPO-10666)

Circle 8 on Reader Service Card.

Section 2. Spectroscopy and General Optics

IMPROVED PHOTOGRAPHIC-FILM RECORDING BY MULTIPLE ELECTRON EXPOSURES

When an image is exposed on a photographic film in certain types of electron-beam recorders, the signal/noise ratio in electron-beam-recorder (EBR) image quality may be improved, along with its radiometric, geometric, and resolution measurements. The underlying idea is to make the input electron signal add repetitive exposures linearly while the noise adds randomly. The resulting signal/noise improvement is proportional to the square root of the number of correlated images scanned on the film before development. The images scanned should be identical to each other so that they superimpose. With two identical images scanned over each other, an improvement in the signal/noise ratio by the $\sqrt{2}$ can be expected.

This technique also makes it possible to average rms current variation, due to electron gun noise, by the multiple-exposure method. Thus, density variation on the film, caused by electron-gun noise or by other electron noise, will be added randomly while the signal will be added linearly. An additional improvement in signal/noise, which is proportional to the square root of the number of exposures, can therefore be expected.

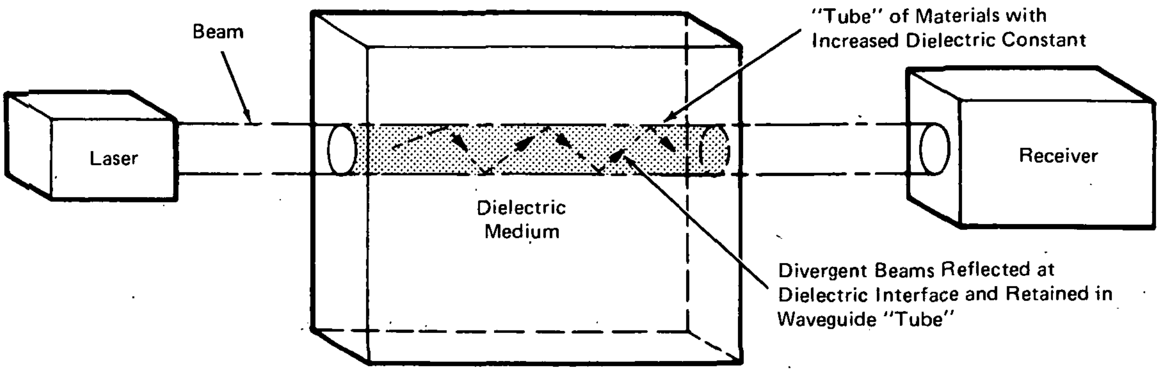
Reducing or averaging the nonlinearity of the EBR scanning position also can be effected by using multiple exposures, with a probable error of 1 part in 5000 due to sweep nonlinearities. Two EBR images of the same scene may be in good registration but actually may be distorted due to sweep nonlinearities. The latter can be averaged by using different portions of the EBR scanning cycle to produce specific portions of the duplicate images.

For example, one line of the image can be written from left to right on the first image, and this same line can be fed into a delay line and can be read in reverse for the second image. Thus, the two images will be identical in registration except for the sweep nonlinearities, which actually will be averaged by producing a multiple-image master more accurate than a single one. Other possible methods include reversing the images from right to left or up and down. The signal/noise ratio is expected to improve by a factor of at least 1.4, when two duplicate images are formed to produce one master image.

Source: A. R. Shulman
Goddard Space Flight Center
(GSC-11524)

No further documentation is available.

TRANSMISSION OF OPTICAL FREQUENCIES WITH MINIMAL LOSSES



Diffractionless-dielectric transfer media have been used to reduce power loss during power transmission at optical frequencies. An optical beam of sufficient power is transmitted through a dielectric medium of a nonlinear refractive index. This transmitting medium may be solid, liquid, or gas with a uniform dielectric constant in the absence of an electrical field; however, gases show the best results. A beam of sufficient power incident on this medium increases its dielectric constant and, thus, self-generates a waveguide through the dielectric of the same diameter and shape as the beam. This effect is similar to that in fiber optics in that all the beam components are self trapped by the total internal reflection. Thus, power loss due to beam spreading between the source and receiver is minimized. The general system diagram is shown in the figure.

To establish internal reflection, the optical beam must exceed a certain critical power P_c expressed in MKS units as:

$$P_c = (1.22\lambda)^2 C/64n$$

where λ is the wavelength, C is the energy flow per unit area, and n is the index of refraction due to electrostriction. Power levels produced in most laser applications are substantially above the critical levels. However, in communications, beam power may be just above the critical levels and may therefore require corrections to achieve self trapping.

Self trapping of the beam is easily induced in steel gas-filled pipes using CO_2. To produce this effect, gas pressure is set as a function of beam power: when beam power is high the pressure should be low and vice versa.

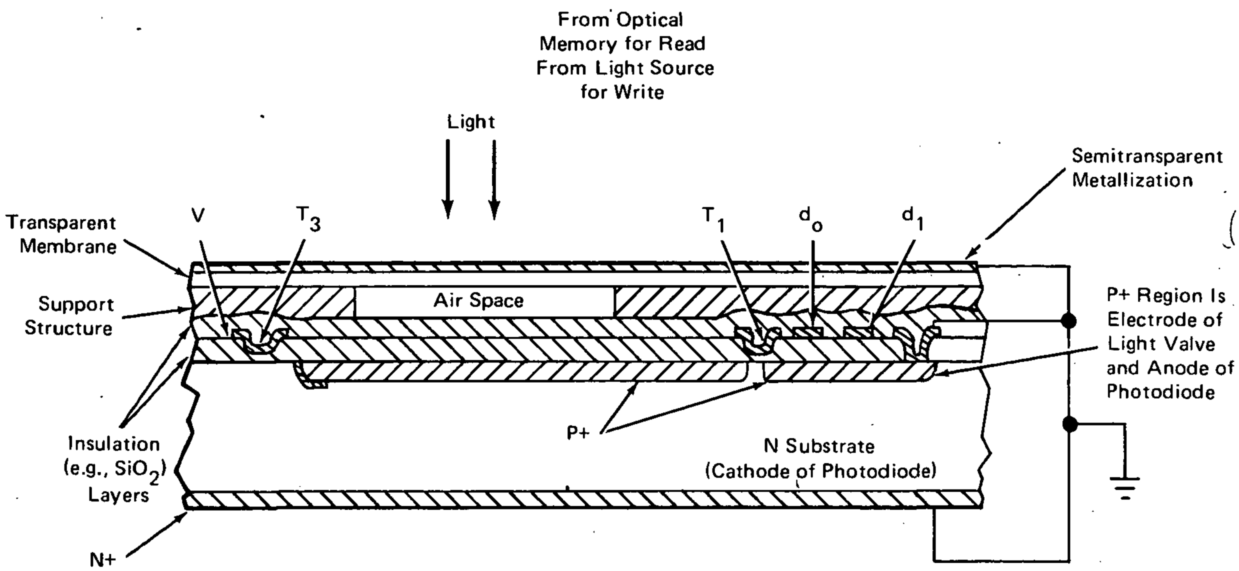
These pipes provide negligible power losses as a result of gas even at high pressures compared to those of liquid or solid dielectrics. Such gas-filled systems are self repairing in that, if gas overheats or ionizes within the beam, it is quickly replaced by the remaining gas in the system.

The developed system can be applied in power transmission, communication, bloodless surgery, machinery, etc. With this concept the laser can be placed remotely from the target area and still provide high power and small beam width.

Source: C. H. Townes, R. Y. Chiao, and E. M. Garmire of Massachusetts Institute of Technology under contract to NASA Headquarters (HQN-10541)

Circle 9 on Reader Service Card.

MEMBRANE LIGHT-VALVE COMPUTER MEMORY



Membrane Light-Valve Element

A new membrane light valve has been developed for electrically and optically accessible computer memories. These memories combine the functions of a page-composer and photodetector. They consist of semiconductor substrates, with memory drivers (e.g., flip-flops) and photodiodes that provide an optical response which determines the state of the transistor memory. In addition, light valves (operated by the flip-flops to assume optically different states) determine the state of a bit in a page of optical memory.

The original liquid-crystal light valve used in these systems may be replaced with a membrane light valve (MLV) which operates in microseconds as compared to milliseconds for the liquid crystal. The MLV has a longer lifetime, no contamination problems, and is more easily fabricated. The MLV is an electrostatically deformable mirror, which can reflect light specularly or, in its deformed state, scatter it over a wide area. Furthermore, the MLV can be made compatible with semiconductor voltages and fabrication techniques.

The integrated assembly is shown in the figure. A single n substrate serves as the photodiode cathode for many elements. Each element is characterized by a p+ region that is both the electrode of the light valve and the anode of its photodiode. The rest of the valve consists of the gap (airspace) in the opaque support structure (to allow light to reach the photodiode) and the semitransparent, metallized membrane.

The membrane can be made to assume two states: When a voltage is applied, (1) it deforms to scatter light and (2) it is semireflective when unenergized. In the reflective state, the semitransparent membrane reflects about one half the incident light and transmits the remainder to the photodiode.

To write into an optical memory or act as a page composer, the state of the MLV is controlled by the transistor memories. To write a "1" the membrane is unenergized and light is reflected to the optical memory. To write a "0", voltage is applied to the membrane and light is scattered randomly.

To read an optical memory signal, the elements act as photo detectors. All elements are in the "clear" unenergized state, and the presence or absence of light is determined from the photodiode outputs.

Source: L. S. Cosentino of
RCA Corp.
under contract to
Marshall Space Flight Center
(MFS-22433)

Circle 10 on Reader Service Card.

SOLID-STATE TELEVISION CAMERA HAS NO IMAGING TUBE

Important advances have been made in recent years in the area of image sensors, particularly in areas of solid-state image converters, and peripheral video and digital-data-handling circuits using large scale integration. A mosaic produced only a few years ago contained 2500 photo-transistors on a single wafer of silicon 1.25 cm (0.5 in.) on a side and arranged in a 50 by 50 square array spaced on 0.25 mm (.001 in.) centers. Since then, three other generations of mosaic arrays have been produced, with the final one containing 200,000 photo-transistors on a single silicon wafer approximately 2.5 cm (1 in.) on a side.

A solid-state television camera that has no imaging tube and has characteristics of a vidicon camera and a resolution greater than the home TV receiver has been developed using a mosaic of photo-transistors. The camera is rectangular in shape, approximately 5 cm (2 in.) by 25 cm (10 in.) by 31 cm (12 in.) and has a 50-mm lens in the center of the large side. The camera has a resolution of 500 lines horizontal and 400 lines vertical, and, due to the completely solid-state construction, it has the usual advantages offered by integrated circuit systems, i.e., reduced weight, volume, and power consumption plus greatly increased reliability and environmental immunity. In addition, the photo-transistor mosaic performs the functions of a vidicon without the necessity for high voltages, magnetic fields, vacuum envelopes, filament power, and protection against mechanical shock. The elimination of the high-voltage requirement is a particularly salient advantage for space environments. The fact that the image plane of the sensor consists of discrete sensor elements, geometrically precise in position, eliminates tube beam deflection errors. These errors are important in optical processing systems such as stereo imaging, motion detection, and scene correlation, where it is important to return to an exactly known segment of the image over relatively long periods of time. The electrical accessing of the image area could also facilitate random scanning in these applications.

Because of its low power and small size, the camera may have a large number of applications. The mosaics can be utilized as cathode-ray tubes and analog-to-digital converters, for the assessment of nuclear blasts.

Source: C. T. Huggins
Marshall Space Flight Center
(MFS-21553)

Circle 11 on Reader Service Card.

ADVANCES IN HIGH-RESOLUTION X-RAY PHOTOGRAPHY

X-ray photography is frequently used in the non-destructive testing (NDT) of metallurgical specimens. Several new techniques have been devised to allow improved resolution and magnification with this technique.

One improvement involves the substitution of a metallurgical metallograph for a conventional enlarger. With the metallograph, magnification up to 1000X is possible as compared to a limit of 25X with the conventional enlarger.

In another improvement, high-speed fine-grain microfilm is used in place of conventional X-ray film. Microfilm has not been used previously for X-ray work because it is somewhat slow; however, the increased resolution of the microfilm more than compensates for the modest loss in film speed.

Another new high-resolution X-ray photography technique has been developed for testing solder joints. The process has been compared with 23 other NDT processes, and it is the only one that is successful with conformal coated joints, both during fabrication and after use. With this process, cracks 0.007 to 0.017 cm (5 to 7 mil) in depth can be detected, even though they are not visible from the surface of the joint. The method requires a small X-ray target source (0.7 mm or smaller), high-resolution film, and magnification of from 10X to 75X.

Source: W. R. Hutchinson of
Martin Marietta Corp.
under contract to
Marshall Space Flight Center
(MFS-21067)

Circle 12 on Reader Service Card.

PINHOLE COLLIMATOR FOR RADIOGRAPHY

A new pinhole collimator may be used to detect nearby sources of radiation. The high-resolution collimator is used to scan an area for an energy source. Radiation incident on the collimator is focused at a single point. With modification the collimator could be used with high-energy electromagnetic radiation as well.

The collimator consists of several plates with randomly placed apertures. The apertures on a given plate are of the same size; the aperture sizes and spacings change from plate to plate, but the relative orientation remains the same. This arrangement produces radiation channels that converge to a single point.

The first plate contains a random distribution of holes of diameter d_1, covering an area $a_1 \cdot b_1$. The second plate contains the same random distribution but contains holes of size d_2, covering a smaller area, $a_2 \cdot b_2$. Each plate has successively smaller holes, covering correspondingly smaller areaa. The holes are sized so that

$$\frac{d_1}{a_n} = \frac{a_1}{a_n} = \frac{b_1}{b_n}$$

These ratios determine the spacings required, to insure that lines drawn through the centers of corresponding pinholes will all converge to a single point. The spacings are found from the following proportionality:

$$\frac{s_1}{d_1} = \frac{s_n}{d_n},$$

where s_n is the distance between the nth and the (n+1) th plate.

The holes in each plate can be photoetched from a single master plate. The master plate is put into a photographic enlarger, and the image is focused on the plates to be photoetched. The hole size is determined by the enlargement, and the relative orientation of the holes is kept the same for each plate.

Source: R. B. Hoover and J. H. Underwood
Marshall Space Flight Center
(MFS-20932)

Circle 13 on Reader Service Card.

OPERATION OF ALKALI VAPOR LAMPS IN NONVACUUM ENVIRONMENTS

Alkali vapor pump lamps for lasers normally are operated in a vacuum environment. However, it has been found that the lamps also can operate in an inert atmosphere such as argon without affecting laser output power. The argon gas surrounding the lamps prevents oxidation of the refractory metals used in the lamp assemblies.

To achieve high laser outputs, it is frequently necessary to operate the lamps at powers higher than their vacuum ratings. This results in increased temperatures that drastically reduce the strength of the sapphire envelopes. The use of argon also acts as a coolant, providing conductive heat transfer that keeps these temperatures within reasonable limits.

In addition, since most of the long-wavelength blackbody emission from a system stems from the hot alumina envelope, the reduction of the wall temperature (by about 200° C) reduces the blackbody-radiated contribution by a factor of two.

Source: K. Ward of
Holobeam, Inc.
under contract to
Goddard Space Flight Center
(GSC-11755)

Circle 14 on Reader Service Card.

MICROSCOPE EYEPIECE FOR CONCENTRICITY INSPECTION

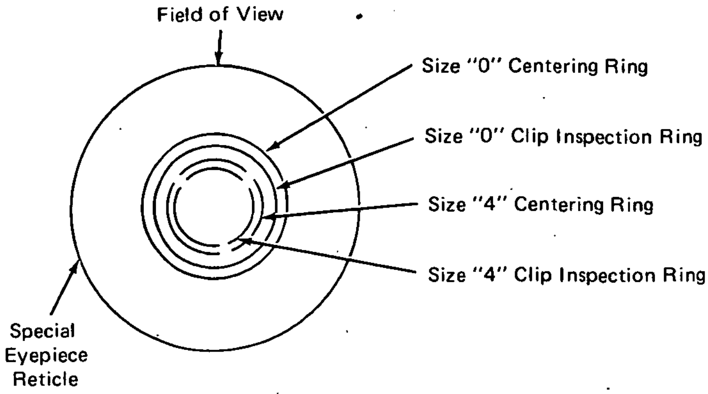


Figure 1. Etched Eyepiece

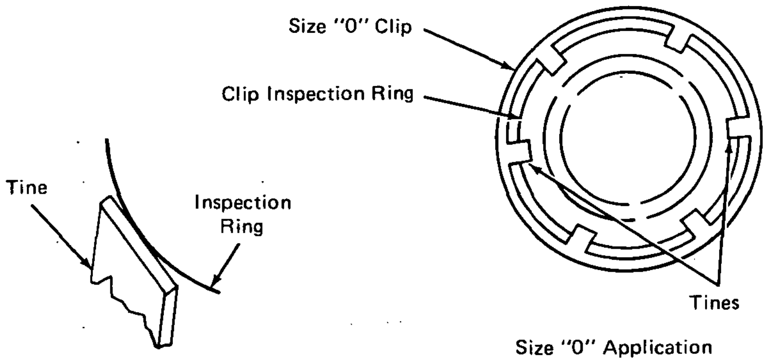


Figure 2. Eyepiece Used to Inspect Tines and Clips

A newly designed eyepiece allows microscopic inspection for concentricity without physically touching the object with gauging tools. To check the position of tines and retention clips, a standard microscope eyepiece is etched precisely with lines that define the physical dimensions of the parts (see Figure 1). As the parts are viewed under the microscope, they are aligned with the superimposed image produced by the etched eyepiece (see Figure 2). Any divergence of the part from the optical limits is definitely established.

Source: J. M. Beekman and E. O. Brunskow of Rockwell International Corp. under contract to Marshall Space Flight Center (MFS-24060)

Circle 15 on Reader Service Card.

SPECTRAL MATCHING OF ALKALI-METAL VAPOR LAMPS USING TOTAL FLUORESCENCE MEASUREMENTS

The optimum-fill ratio has been determined for potassium/rubidium (K/Rb) lamps [used to excite a neodymium/YAG (Nd/YAG) laser]. The individual components of the K/Rb mixture have been analyzed spectroscopically at varying vapor pressures. From this, the contribution of each component to the total fluorescence of the laser output is found. To find the optimum spectral match, a lamp with a rubidium fill is operated in an integrating sphere. The total fluorescence is recorded with a scanning spectrometer through the zero order (i.e., all radiation entering the collecting optics of the spectrometer is transmitted into the fluorescence cell). Filters exclude most radiation beyond 8600 Å, thus limiting the total fluorescence to the contributions from the Nd/YAG 7300 through 8300 Å. The integrated total fluorescence and the total fluorescence measurement agree to within 20 percent, which is adequate for optimization tests.

Instead of repeating the measurements with a pure potassium lamp, an empirical method of varying the weight ratios and the mole fractions of the Rb and K components was developed and used (with experimental verification) to determine the optimum fill. The optimum calculated K/Rb pressure ratios are as follows:

Tube Diameter (mm)	Ratio
2	5/1
3	2.2/1
4	1.25/1
5	0.8/1
6	0.55/1

It can quickly be appreciated from the above table that the pressure ratios vary as the square of the tube diameter. This means that discharges in different-size envelopes still maintain similar arc properties (i.e., temperature and radiation), if the product of the diameter (or radius) squared and the vapor pressure (or pressure ratio) is a constant.

Source: K. Ward of Holobeam, Inc.
under contract to
Goddard Space Flight Center
(GSC-11753)

Circle 16 on Reader Service Card.

Section 3. Photography and Film

ROTARY SOLENOID SHUTTER

A rotary solenoid is used to drive the shutter in a highly-precise shutter assembly. It provides 4- to 16-millisecond exposure times, with less than 5 percent variation in aperture size and exposure time. The assembly consists of a Tee-shaped frame which mounts two rails, each bearing a rotary solenoid. The frame also mounts a set of gibs which guide the two shutter blades. The solenoid-drive arms move the blades through a single-link system, using bushings at the pivot points of the link.

The shutter allows uniform exposure across the aperture and repeatable exposure times, over a temperature range of 0° to 50° C (32° to 122° F). This performance is consistent for a life of one million cycles in a vacuum of 10^{-5} torr. Only a simple adjustment of the inputs to the direct and delay solenoids is required to maintain this accuracy. The direct blade of the shutter exposes the aperture, while the delay blade follows to close the aperture; thus, a moving slit travels across the aperture. Longer exposure times are obtained by increasing the time delay between the instants of applying power to the direct solenoid and to the delay solenoid.

Another practical application is the possibility of the rapid insertion and retraction of lens filters on cameras. The filters merely replace the shutter blades and are held and driven on command through the rotary solenoids.

Source: W. L. Cable and H. B. Dougherty of
RCA Corp.
under contract to
Goddard Space Flight Center
(GSC-11561)

Circle 17 on Reader Service Card.

ROTARY-INERTIA DAMPER AND STOP-PLATE ASSEMBLY

A new rotary damper reduces the stroke rebound effect (bounce) of a camera shutter. It is specifically designed for use with the shutter described in the previous article, but may also be used with other systems.

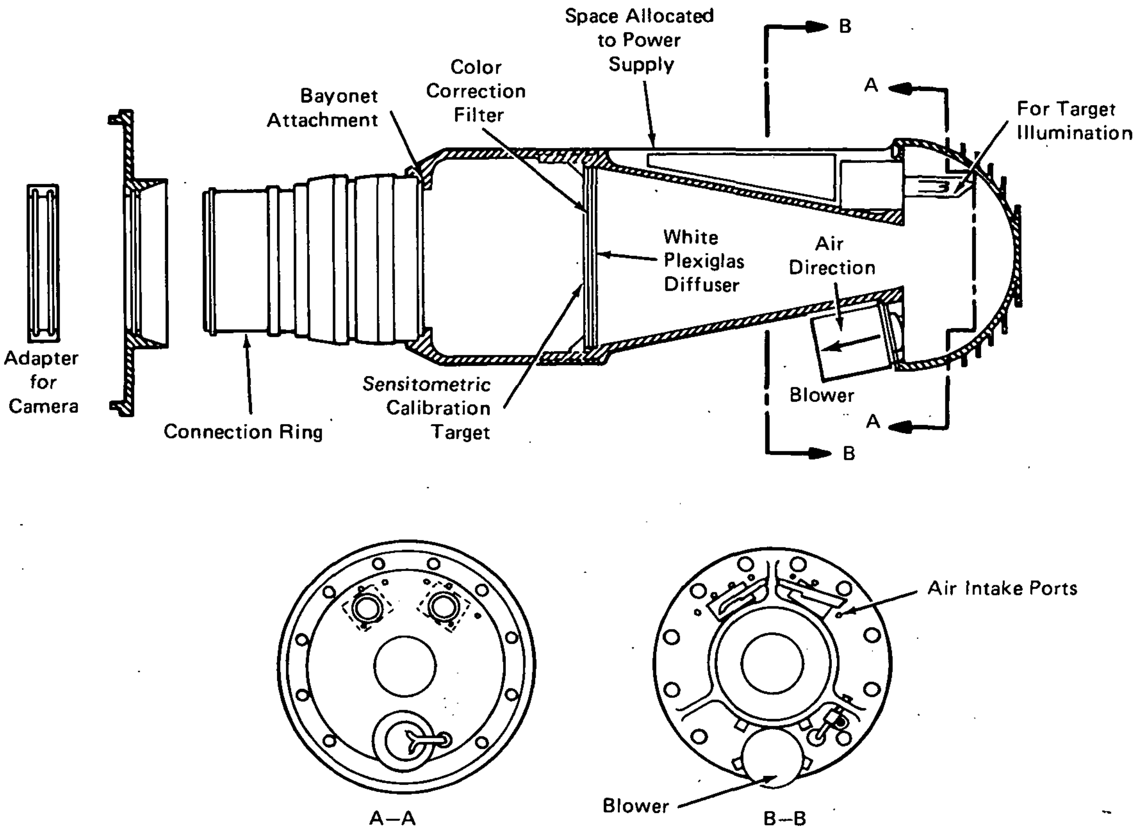
The assembly consists of a stop plate, which is riveted to a heavy metal ring containing a bushing. The plate is a limit stop for the solenoid armature stroke. In principle, the inertia of the damper is matched with that of the rest of the armature/linkage/blade system, in an approximate ratio of 1 to 2. Peripheral rotation of the shutter beyond the point of initial impact is limited to approximately 0.051 cm (0.020 in.).

The matched inertias and the controlled overtravel regulate the multiple-collision reaction of the armature/blade system against the stop plate. In this way, the coefficient of restitution in the system, and thus the bounce at the end of a stroke, are reduced, and double exposure is eliminated.

Source: W. L. Cable of
RCA Corp.
under contract to
Goddard Space Flight Center
(GSC-11560)

Circle 18 on Reader Service Card.

FILM-CALIBRATION SYSTEM FOR CAMERAS



Film-Calibration System

Compact size, stability, and a highly refined sensitometer are the advantages of a new film-calibration method. A light source with a stable output is used to expose a frame of film that can be compared with film exposed in the machine at other times.

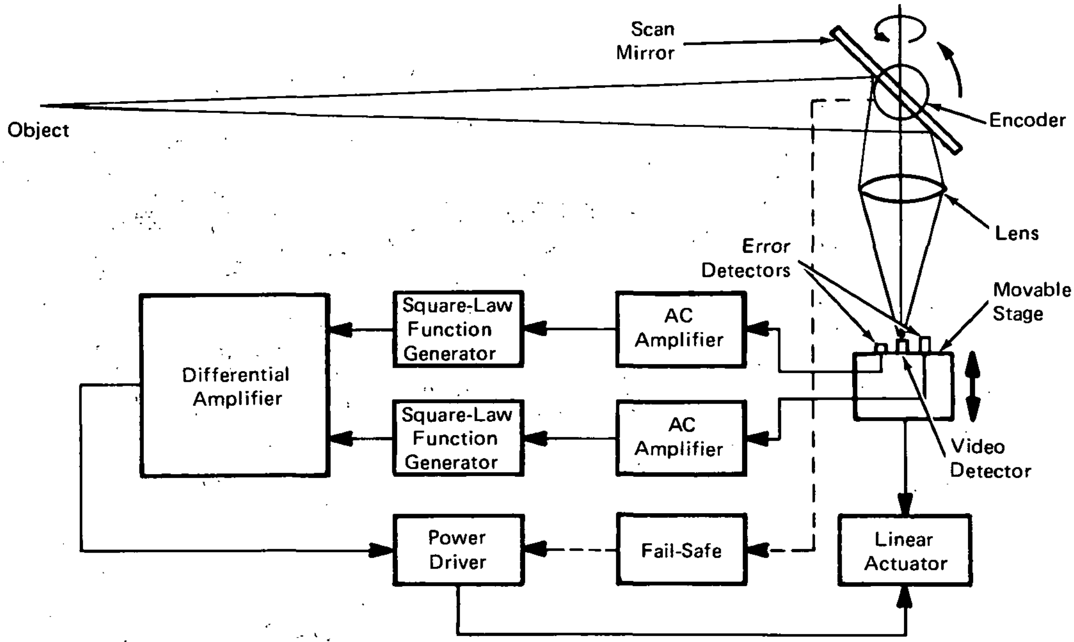
The film-calibration system is a semiportable unit about 36.8 cm (14.5 in.) long and 10.16 cm (4 in.) in diameter, which must be positioned in a camera loaded with the film to be calibrated. The illustration shows the lens system, a calibration target, a target-illumination system, and a regulated power supply. The lens of the calibration system is connected directly to the lens of the camera via a connection-ring adapter.

With the camera lens focused at infinity, the calibration system provides a full-frame projection of the target on the film plane. This projected image is recorded on the film through the normal camera-exposure sequence. The camera-shutter speed and the f-number settings must be set according to the original calibrations. These settings are used as standard in measuring and correcting any changes (degradation). Corrections can be made on the second-generation film.

Source: L. P. Oldham of
Martin Marietta Corp.
under contract to
Marshall Space Flight Center
(MFS-21272)

Circle 19 on Reader Service Card.

AUTOMATIC FOCUS CONTROL FOR FACSIMILE CAMERA



Basic Components of the Atomic Focus System

This automatic focus control performs the function of automatically focusing a facsimile camera throughout an object field being scanned. It does this by determining the correct focus point for objects, as they are scanned, and adjusting the focus of the imaging sensor accordingly. Since the facsimile camera images a scene by scanning discrete strips, it is possible to have the entire three-dimensional scene in perfect focus at the point of imaging by use of this automatic focus control.

The basic components of the automatic focus system are schematically shown in the illustration. They consist of a movable stage, containing two photodetectors for sensing and one or more imaging sensors, which is connected to an electromagnetic linear actuator and the electronics equipment. The two focus detection sensors are placed with one closer to the lens than the imaging sensor, which produces the video data in the fashion standard to facsimile cameras, and the other farther away. The actuator is similar to a common speaker voice coil; and the primary actuator is driven by an error signal, which is the difference in focus sensor outputs. The electronics equipment consists of balanced ac amplifiers, two square-law function generators, a differential amplifier, and a power drive.

The two facsimile-camera focus sensors scan a line of a three-dimensional scene, with the first slightly before and second slightly behind the imaging sensor, and have a field of view equal to that of the imaging sensor. As the focus sensors scan, they receive varying light intensities and produce signals which may be equal or normally different. The fail-safe circuit is included because of the equal signals which would be produced by the focus sensors looking at a blank wall or shadow; by use of the secondary actuator, this circuit prevents excessive excursions in the primary actuator servo when true video is reacquired. When the scan produces the normally different signals, the signal from the detector in best focus will show the most ac components. The signals are passed through the ac amplifiers to drive separate function modules, which square the individual signals. Each signal is then filtered and applied to inverting and noninverting inputs of the differential amplifier. The output (signal difference) drives the input of the power driver and primary linear actuator. The servo drives the actuator until there is equal signal from each focus sensor. The imaging sensor, mounted on the movable stage at the calculated focus point between the focus sensors, is then in focus.

Source: A. R. Sinclair, S. J. Katzberg, and
E. E. Burcher
Langley Research Center
(LAR-11213)

Circle 20 on Reader Service Card.

Patent Information

The following innovations, described in this Compilation, have been patented or are being considered for patent action as indicated below.

Inquiries concerning rights for the commercial use of the inventions described below should be addressed to:

Patent Counsel
Marshall Space Flight Center
Code CC01
Marshall Space Flight Center, Alabama 35812

Broadband Modulation-Index Meter (Page 2) MFS-22740

Development of a Three-Dimensional Laser-Doppler System (Page 6) MFS-22669

A Holographic Viewing System for Large Audiences (Page 8) MFS-22723

Three-Dimensional Gas Turbulence Measurement With a Laser-Doppler Velocimeter System (Page 11) MFS-22713

Membrane Light-Value Page-Composer/Photodetector (Page 19) MFS-22433

Solid-State Television Camera Has No Imaging Tube (Page 20) MFS-21553

Pinhole Collimator for Radiography (Page 21) MFS-20932

Microscope Eyepiece (Page 22) MFS-24060

The inventions described below are owned by NASA, and patent applications have been filed. Inquiries concerning nonexclusive or exclusive license for their development should be addressed to:

Patent Counsel
Langley Research Center
Code 456
Hampton, Virginia 23665

A Laser Head for Simultaneous Optical Pumping of Several Dye Lasers (Page 14) LAR-11341

Automatic Focus Control for Facsimile Camera (Page 26) LAR-11213

Laser System Detects Air Turbulence (Page 15) MFS-21244

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial use should be directed to:

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Marshall Space Flight Center, Alabama 35812

Transmission of Optical Frequencies With Minimal Losses (Page 18) HQN-10541

This invention has been patented by NASA (U.S. Patent Nos. 3,556,634; 3,571,555; 3,575,602; and 3,606,522). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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NASA Headquarters
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Washington, D. C. 20546

NASA-Langley, 1976