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A PRELIMINARY INVESTIGATION OF LASER ACTION ASSISTED BY OXIDIZED HYDROCARBONS

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Grant Number NsG-74-60

1093-32 7 October 1966

Prepared for:
National Aeronautics and Space Administration
Office of Grants and Research Contracts
Washington, D.C. 20546

Department of ELECTRICAL ENGINEERING

THE OHIO STATE UNIVERSITY
RESEARCH FOUNDATION
Columbus, Ohio

NOTICES

REPORT 1093-32

REPORT
by
THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION
COLUMBUS, OHIO 43212

Sponsor	National Aeronautics and Space Administration Office of Grants and Research Contracts Washington, D.C. 20546
Grant Number	NsG-74-60
Investigation of	Receiver Techniques and Detectors for Use at Millimeter and Submillimeter Wave Lengths
Subject of Report	A Preliminary Investigation of Laser Action Assisted by Oxidized Hydrocarbons
Submitted by	Benjamin Franklin Jacoby Antenna Laboratory Department of Electrical Engineering
Date	7 October 1966

N67 12260

ABSTRACT

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This report describes the apparatus constructed to investigate the possibility of new laser line in the infrared and far infrared regions and some preliminary results are presented of a study where CO_2 and CO were generated by a chemical reaction within the discharge tube and made to laser.

Author

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A PRELIMINARY INVESTIGATION OF LASER ACTION ASSISTED BY OXIDIZED HYDROCARBONS

I. INTRODUCTION

The development of molecular lasers has shown great promise of producing high-intensity radiation in the submillimeter and far-infrared regions. Previously there had been no truly monochromatic, high-power source of radiation available at these frequencies. Already, powers on the order of several hundred watts have been produced by the N_2-He-CO_2 laser operating at 10μ and low-power laser oscillations have been obtained with a small number of substances in the submillimeter region. Thus, if the mechanisms of molecular laser operation come to be more fully understood and the output frequencies of various laser materials are cataloged properly, it should be possible to construct high-power molecular lasers operating at many frequencies throughout the far-infrared and submillimeter spectrum. The purpose of the study is to investigate new laser materials by cataloging their output frequencies and examining their properties. This report describes the approach and some preliminary results.

II. DESCRIPTION OF APPARATUS

Since the main tool of this study is the laser discharge tube and associated apparatus, it was felt that the design should be as flexible as possible and, in addition, should introduce as little loss as possible into the cavity. Therefore, the discharge tube was constructed of standard 3/4" glass pipe and fittings. Internal mirrors were employed to eliminate Brewster window losses. The remainder of the system was constructed of nylon and copper tubing. Thus, the entire apparatus can be dismantled for cleaning or modification without the aid of a skilled glassblower.

The gas flow and electrode connections to the discharge tube were made with standard glass "T"s, as shown in Fig. 1. Glass pipe is normally joined with bolt flanges and a teflon gasket, but it was found that the teflon would not seal properly unless the glass parts were aligned exactly. However, when the teflon gaskets were replaced with "O" rings no difficulty was experienced in obtaining a tight vacuum seal. Vacuum gauges were provided on both the high- and low-pressure sides of the gas path, and leak valves and flow meters were incorporated to regulate and measure the gas flow through the discharge tube. An overall view of the apparatus is shown in Fig. 2.

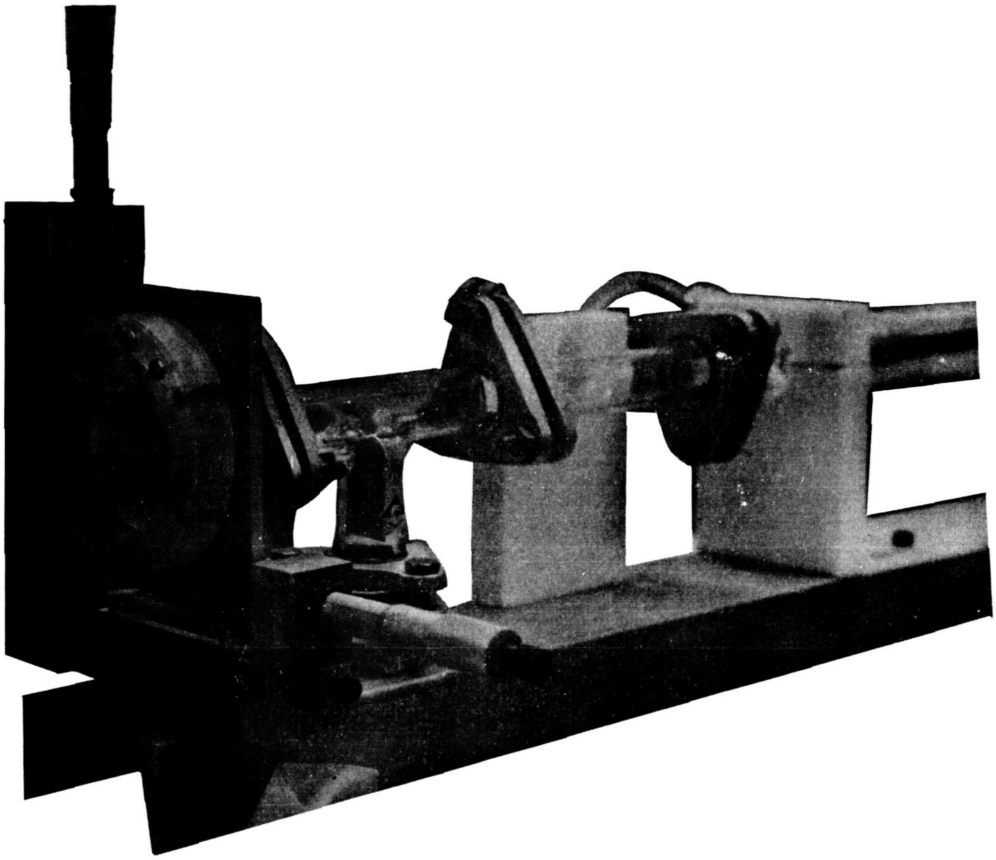

Fig. 1. Electrode and gas flow connections.

The mirrors of the laser cavity were attached to the main portion of the discharge tube with brass bellows which allow sufficient motion to effect optical alignment. The mirrors and bellows are insulated from the grounded micrometer-driven mounting plate by a polystyrene flange so that the gas discharge will be blocked from the shorter path through the bellows to ground. A detailed view of this end assembly is shown in Fig. 3.

The laser output is obtained from a small (1-2 mm) hole in one of the mirrors which is sealed either with a salt (NaCl) flat or with the detector itself. A thermistor in a bridge circuit is normally used to detect the output, although a Golay cell has been used for weak radiation.

The discharge can be excited quasi-CW with a 60 Hz neon-sign transformer, or pulsed with a hard-tube pulser. The transformer can provide up to 60 mA of alternating current, while the pulser can provide μs pulses many amperes in magnitude. A new liquid-helium-cooled, high-speed detector will soon be available and, when used in conjunction

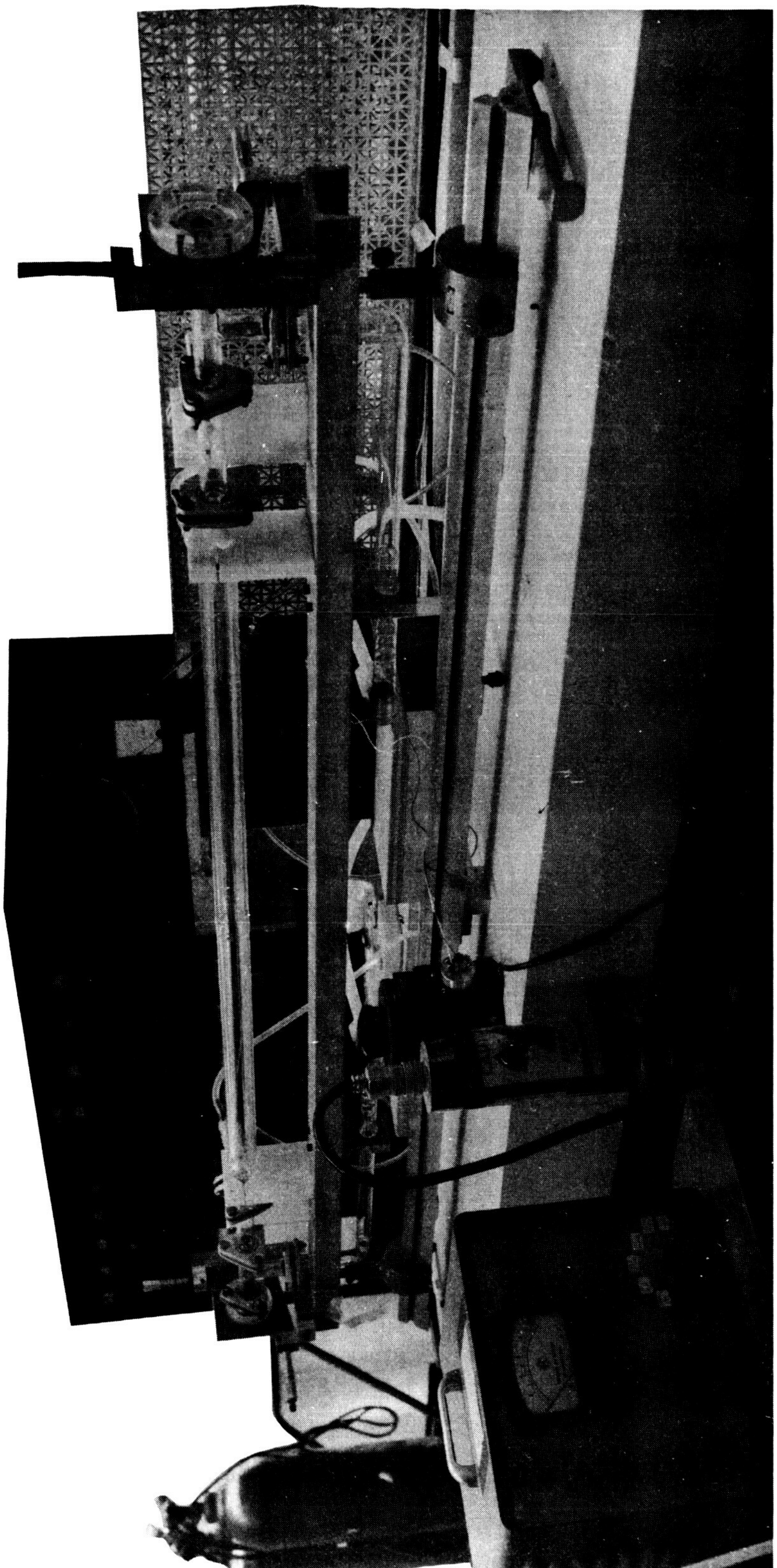

Fig. 2. Apparatus.

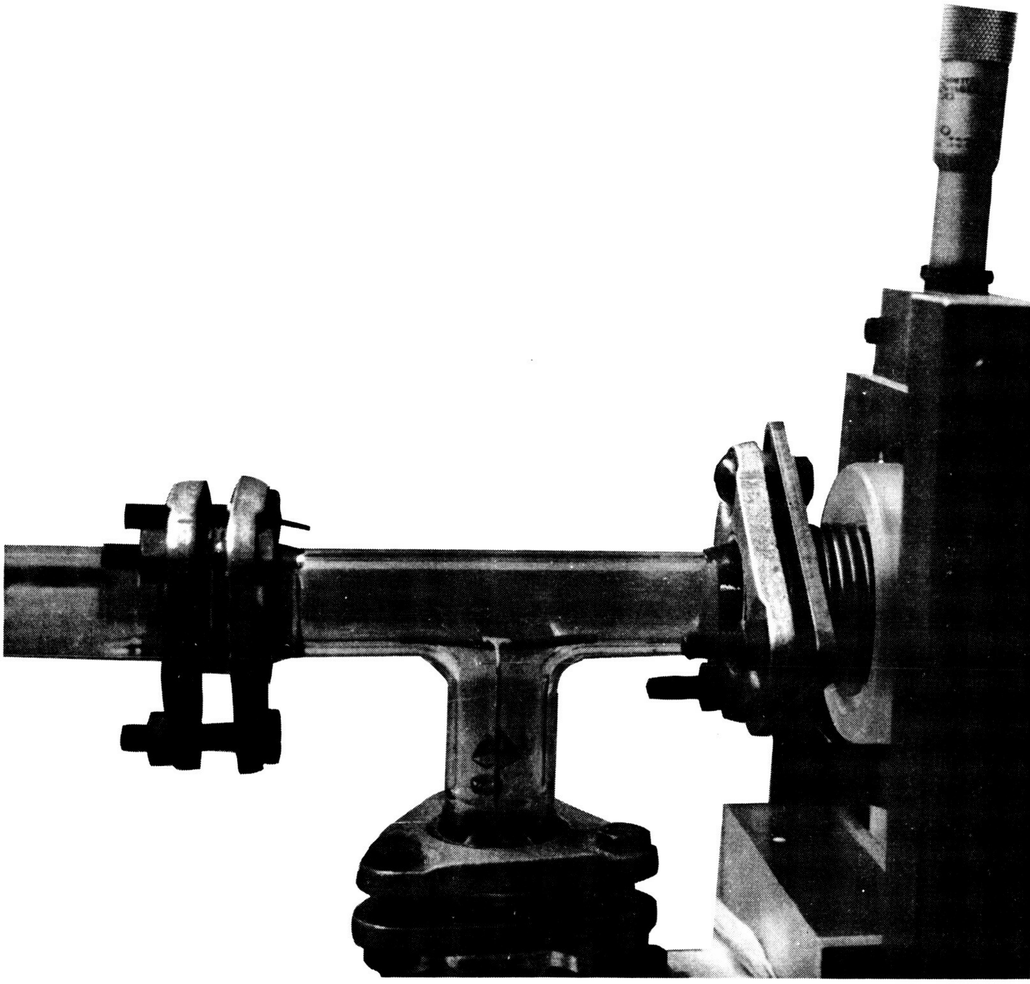

Fig. 3. Bellows detail.

with the pulser, should prove to be a useful tool in the study of inversion mechanisms and cascade effects.

One of the first modifications to the original design was the addition of a cooling jacket around the major length of the discharge tube. This jacket provides a larger and more stable output for most molecular systems. While cold water is the usual coolant, a system has been built which circulates alcohol. The alcohol is pre-cooled by passing it through coils in a container which can be filled with a slurry, such as ice and water or dry ice and alcohol, to obtain a wide variety of jacket temperatures. In all, the laser design has proven to be a useful and easily modified experimental tool.

III. RESEARCH TO DATE

Since the purpose of this research is to study new laser transitions in the far-infrared and submillimeter regions, it was felt that the most fruitful approach would be to obtain laser action on several known transitions in order to optimize the equipment, and then to examine systematically new substances for laser action.

CO_2 in a CO_2-N_2-He system was tried initially and made to laser. However, it was discovered that prolonged operation at high power levels would cause the output mirror to crack from heating around the coupling hole as a result of the intense radiation. Subsequently, a more or less conical hole was employed in an attempt to keep the output radiation from heating the glass but, although some improvement in performance was observed, the mirror would still crack at high power levels.

CO was also made to lase in an N_2-CO system, but although considerable output power was observed no attempt was made to study this gas system in detail.

Acetylene was tried as an active substance together with mixtures of other gases in both flow and non-flow systems, but no laser action was observed. Furthermore, a brown deposit was seen to form on the inside of the discharge tube. It is believed these difficulties could be caused by the conventional-grade acetylene, (shipped dissolved in another substance for safety) used in these experiments. The experiments are scheduled to be repeated with 99.6% pure acetylene.

An attempt was made to produce laser action in ammonia but, again, none was observed. Since ammonia has a large number of closely spaced energy levels, it seems likely that excited states may quickly cascade down to the ground state without producing a population inversion capable of infrared laser action. However, this close spacing could lead to laser action at much longer wavelengths and a submillimeter investigation could prove fruitful.

Finally, many hydrocarbons were tried and all were observed to lase strongly in a flow system with air. Acetone (CH_3 CO CH_3), ethyl alcohol (CH_3 OH), benzene (C_6 H_6), toluene (C_6 H_5 CH_3), illuminating gas (mostly CH_4), and xylene (C_6 H_4 $(CH_3)_2$) all produce strong laser action at wavelengths observed to be identical with either those of CO_2 or CO, depending upon the various partial pressures.

It was also observed that the constituent parts of air needed for laser action are oxygen and nitrogen, and that a mixture of these two gases works as well as air in the laser. At present, it is believed that the oxygen is oxidizing the hydrocarbons to form CO_2, CO, and H_2O and that the CO_2 or the CO then operates as an N_2 - CO_2 or N_2 - CO laser. It is very possible that the heat of reaction of the living hydrocarbons could contribute to the population inversion.

In addition to the flow investigation, an acetone-air laser was operated for 25 minutes with no gas flow. At first, the output level fluctuated greatly but stabilized in about 5 to 10 minutes. The power then began to increase and continued to do so until 25 minutes had elapsed, at which time the output mirror cracked from the heat generated by the intense radiation. It was also observed that the intense internal radiation had melted the gold coating on the other mirror.

Clearly, the possibilities for far-infrared or submillimeter lasers with chemically aided population inversion seem quite promising, although much work remains yet to be done. Future work in this area will consist in studying chemical reactions of hydrocarbons, and some of the other chemicals, for possible laser action in the far-infrared region. To date measurements of all of the wavelengths observed have not been carried out. It is possible that the heat of reaction could activate some of the higher J-rotational levels or cause inversion of some of the vibrational levels. So far we have examined only those wavelengths below 10.6μ which the salt crystal can pass. A study is underway using other windows for the detection of laser action.

A number of experiments using the short-pulse duration, high-voltage pulser have been planned. It is believed that disassociation and incomplete burning of the molecules (when subjected to the high current discharge) will produce chemical radicals which may be suitable for laser action in the far-infrared region. For this purpose an indium-doped germanium detector has been obtained to investigate the short-duration pulses. Of course, it is not possible to predict exactly what wavelength, if any, will be obtained but a systematic study of the simple carbohydrates, or some of the other chemicals, under both steady-state cw conditions and in the pulse regime may reveal some new coherent sources.

ACKNOWLEDGEMENT

The suggestion for this line of experiments came from Professor S.H. Koozekanani, and his interest and advice are gratefully acknowledged.