Report No. 68-58
October 1968

I R LASERS AND OPTICAL PROPERTIES

Semi-Annual Report
10-31-68
NASA Research Grant NGL 05 007-161

O. M. Stafsudd
Principal Investigator

GPO PRICE $

CFSTI PRICE(S) $

Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

FACILITY FORM 602

N68-37839 (ACCESSION NUMBER)

(THRU)

7 (PAGES)

1 (CODE)

CR-97315 (NASA CR OR TMX OR AD NUMBER)

16 (CATEGORY)

RECEIVED
NASA STI FACILITY
INPUT BRANCH
NOV 1968

Department of Engineering
University of California
Los Angeles, California

Current Projects

The research at this time has been divided into five major areas: (1) Far infrared laser construction and operation, (2) Brewster window experiments, (3) Gain measurement, (4) "Q" switching experiments, and (5) Materials preparation and measurement. Each of these areas will be discussed separately in this report in the interest of clarity; and a final section on "Future Studies" is also included.

(1) Far Infrared Laser Construction and Operation

Two separate far infrared lasers have been constructed by this group. Both have interchangeable water-cooled jackets which allow the bore size of the discharge to be changed from 1 to 2, 3, or 4 inches by merely bolting in a new tube and adapter.

The length of the lasers is nominally 2.5 meters but can be varied from 1 to 4 meters by changing the length of the discharge tube. At this time, a C. W. Power output of 1-2 milliwatt is available at 120 microns from water vapor. The power output of the same laser at 337 microns from HCN is about 100 milliwatts under the best conditions and always better than 70 milliwatts. The lasers have a long term stability of about ±1% in output power when scanned continuously.

(2) Brewster Window Experiments

All attempts to construct a C. W. Brewster windowed water vapor laser met with failure. In order to discover the cause of the failure, a special test cell was constructed and placed inside the laser cavity. The cell consisted of a 6" x 3" Pyrex cross with feed-throughs to allow window material to be inserted into the optical cavity without distortion of the window due to pressure on one side or absorption due to gases outside the window. Window materials tested were: high density polyethylene, polypropylene, teflon, kel-F, mylar, methyl-methracolate (lucite, and natural crystal quartz).

All of these materials proved unsuccessful even in very thin sections, i.e., .00025 inches thickness.

It was noted that the only plausible reason for the failure of a C. W. Brewster system is that the water vapor system has very low gain.

It is known that water vapor will lase under pulsed excitation in a Brewster angle window system. But it is also known that pulsed gains are almost universally higher than C. W. gains. In order to test this hypothesis, an experiment was set up (3) to measure the C. W. gain of the water vapor and HCN laser.

(3) Gain Measurements

The only references to gain in far infrared lasers in the literature at this time are not direct measurements but rather inferred by calculating the losses in the laser cavities. We have set out to measure the gain directly.

The output of a 2.5 meter long 7.5 cm diameter oscillator is passed through a 2 meter long 5.0 cm diameter amplifier tube. The energy from the amplifier tube is collected by a spherical mirror and sent to the detector system. The detector consists of either a Golay cell or thermopile, preamplifiers, and lock-in amplifier.

The energy output of the oscillator alone is measured first and then the amplifier tube is turned on and the new energy is measured.

The energy increase follows the usual expression:

$$I = I_o e^{\alpha \ell} \qquad \alpha = \text{gain in fraction or d.b. per meter}$$

The C. W. gain of water vapor has been determined to be less than 1% per meter. This is the current minimum detectable gain of the equipment. This result confirms the previously suggested reason for the failure of Brewster windowed water vapor lasers. The gain of the HCN laser is now being investigated. The preliminary results in HCN indicate that considerable gain is available, i.e., using CH_3CN gas, a current of 400 milliampere, at a pressure of 500 microns, the gain was found to be +.150/meter. This is about 1.3 d.b. per meter. It has been noted that higher gains can be obtained in other gases. The gain was nominally the same for both the 311 and 337 micron lines.

(4) "Q" Switching

A rotating "Q" switch has been constructed and tested. The rotating flat mirror has a 1-7/8 inch useful aperature and rotates inside the vacuum system of the laser (intra-cavity). The maximum frequency is 200 pulses/second, which corresponds to 12,000 RPM. "Q" switched operation has been obtained with CO_2 - N_2 mixtures and multikilowatt pulses result. The "Q" switching system is constructed in such a manner that it can be interchanged with the fixed end of either of the far infrared lasers (Section 1) that have been constructed. No "Q" switching has been observed with water vapor.

The system is being readied for a similar experiment with HCN.

(5) Materials Preparation and Measurement

It is well known that for simple tasks, such as image formation and general geometrical optical problems that most of the problems can be solved with either conventional mirror (reflection) optics or plastic, polyethylene, etc., lenses. However, problems such as modulation and mixing remain unsolved mainly due to a lack of suitable materials.

At this time, two screens of modulation seem quite plausible. The first utilizing the electro-optic effect and the second, free carrier absorption. The first, electro-optic, method requires a material which is highly polarizable and also, of course, transparent in the wavelength of interest. These requirements are the same as those necessary for a material to be a good optical mixer with the additional requirement of transparency in other wavelength regions, i.e., pump and sum or difference wavelengths.

Because of the similarity of these requirements, a dual purpose literature search has been undertaken. This investigation has been completed and the results are being tabulated and will be submitted as a separate report.

The guidelines for this search have been:

Suitable crystal structure, ease of possible crystal growth, and chemical composition.

A large number of compounds can be ignored immediately due to their composition. That is to say, we are particularly interested in compounds which are highly polarizable and transparent in the infrared. Most sulfides, selenites, tellurides, and iodides satisfy these requirements and the literature search and experiments have largely been devoted to this group of compounds.

In particular, at this time, crystal growing efforts are being made on sulfur, selenium sulfide, selenium disulfide, and lead iodide. Preliminary results on the single crystal sulfur (orthorhombic form from solution) indicate numerous absorption bands in the 2.5 to 25 micron region. Notably however, the material is quite transparent in the 2.5 to 7.2 micron and 8 to 10.4 micron region.

Tests are now underway to determine its far infrared properties.

Future Studies

The current plan for extending the areas of work now in progress are as follows:

1. Improved Far Infrared Laser Construction

In the light of the gain measurements made at this time, we can predict the successful construction of a Brewster-windowed C.W. HCN laser. Following this construction a frequency and amplitude stabilized Laser for investigation of electro-optic modulation, free carrier modulation and optical mixing will be built.

2. Conclusion of "Q" Switch Experiments

The final experiments are currently being conducted on a "Q" switching system for far infrared lasers. A conclusive experiment will be completed within two weeks. After these experiments, the "Q" switch will be converted to CO_2 operation to provide the powerful "pump signal" necessary to evaluate the optical mixing contents of the single crystals being grown.

3. Gain Measurements

The gain measurements of HCN which have just been successfully started will be continued and will extend, hopefully, to the measurement of the radial dependence of the gain, bore diameter dependence, and of course, pressure and current dependence.

It has already been found that there is little or no wall temperature dependence on the gain.

4. Development of New Materials

The literature search, referred to earlier in this report, has indicated that the following materials most likely to be of interest are shown in Table I.

TABLE I

Material	Method of Crystal Growth	Status
S	Solvent CS_2, C_6H_6 evaporation and extraction	Already yielding optical quality crystals of small 5 mm size
Se S	Bridgman	Yields glass Amorphous material
	Solvent - extraction	Slow growth ≈ 1 mm cubes of good quality in 4 days, promising results
PbI_2	Solution	Poor results so far, decomposition occurs
Hg S	Vapor transport cubic form (meta cinnabar)	Preliminary results only. It appears that it may be difficult to obtain materials with low enough carrier concentration
Hg S	Solvent (Hexagonal cinnabar)	Due to the very low solubility in H_2O and alkali halide solutions, no crystals of any size have been obtained. However, molten alkali sulfides, disulfides, and hydrated sulfies may yield better results