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APPLIED RESEARCH LABORATORY

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FACILITY FORM 602

N65-21342 (ACCESSION NUMBER)	(THRU)
7 (PAGES)	1 (CODE)
CR 57922 (NASA CR OR TMX OR AD NUMBER)	16 (CATEGORY)

15 February 1965

TO:
National Aeronautics and Space Administration
Goddard Space Flight Center
Glenn Dale Road
Greenbelt, Maryland 20771
Attention: Contracting Officer, Code 248

SUBJECT: Theoretical and Experimental Investigation on Modulation-Inducing Retrodirective Optical Systems (MIROS). Contract NAS 5-9765 (Philco B006), Monthly Contract Progress Report No. 3 for the period 20 December 1964 to 20 January 1965.

SUMMARY OF WORK ACCOMPLISHED DURING THE REPORT PERIOD

To improve the Q-switched laser beam, the existing experimental apparatus was modified. Continued effort was devoted to fabricating injection lasers which lased at the resonance D lines of the cesium vapor. Further experiments on the modulation of single-crystal SbSI at higher frequencies were carried out during the report period.

1. Experimental Activities

A. GaAs Lasers

A special diode mount for GaAs lasers was fabricated and tested during the past month. It consisted of two copper electrodes, one fixed in a nylon cylinder, and the second free to slide under spring tension in the upper half of the same cylinder. The electrodes were 3/8 inch in diameter, with 3/32-inch diameter faces that were lapped flat and parallel, and plated with indium. Diodes with epitaxial-grown junctions and ohmic contacts of sintered nickel were used. The complete unit had a series resistance of 0.2 to 0.3 ohm.

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At 77°K these units lased at around 8340 Å with a threshold of 4×10^3 amp/cm^2, using 2-microsecond pulses at a low repetition rate. The spectral peak at the threshold is approximately 200 Å lower than reported[1] for identical material, using conventional soldering techniques. This is an indication of a lower effective junction temperature with a corresponding wider band gap ($\sim$ 0.04 ev). However, the thresholds are twice as high as the best conventional units of the same material. When the diodes were removed, they were found to have sunk a few mils into the electrode surface. The crystal faces were probably damaged in the process, which increased the cavity losses. Electrodes of tellurium copper have been made and should provide a firmer base.

In an attempt to construct a lasing diode from closely compensated GaAs, a wafer which was less closely compensated than those used previously was divided into three sections for separate diffusions of zinc and cadmium; the third section was used as a control. The compensated ratio, N_D/N_A, was 1.3 with $N_D = 8.4 \times 10^{17}$ cm^{-3}.

A probe test of the diffused samples showed the zinc-diffused piece to be strong p-type, the cadmium-diffused piece to be moderately p-type, and the control to be very weakly p-type at the surface. Angle lapping and staining with Cu showed the junctions to be 120 μ, 8.5 μ, and much less than 1.0 μ in the zinc-diffused, cadmium-diffused, and control samples, respectively.

Diodes have been prepared from the diffused samples. Electroluminescence in the cadmium-diffused diodes showed emission peaks at 8450 Å. Line narrowing to about 60 Å was observed, but the laser action has not yet been observed. The zinc-diffused diodes also radiated at 8450 Å.

It is interesting to note that negative resistance has been observed in the forward current-voltage characteristic of the cadmium-diffused diodes. A typical diode will be insulating to 2 volts before dropping back to 1.5 volts and conducting. This may be caused by the close compensation of the material and the formation of a semi-insulating region on the p-side of the junction at low temperatures. The formation of an insulating layer may cause difficulty in constructing a lasing diode.

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[1] Monthly Contract Progress Report No. 1 (15 December 1964).

B. Generation of Alkaline Line by Stimulated Raman Emission

The efficiency of the optical pumping of a ruby laser depends much upon the reflectivity of the cavity. Thus, to improve the pumping efficiency of the ruby laser, a special silver plating was applied to the existing laser cavity by the American Electroplating Company, Boston, Massachusetts. The silver-plated cavity was observed to have higher pumping efficiency.

The time delay of formation of the Q-switched laser in the previous setup was found to be unstable when the pulse generator (Tektronix Type 161) was triggered by the output from the "Sawtooth A" of the Model 555 oscilloscope. To resolve this difficulty, the experimental apparatus for investigating Raman lasers[2] was modified. Instead of using the "Sawtooth A" output of the 555 scope to trigger the 161 pulse generator, the "Delayed Trigger" output from the 555 scope was fed into the trigger input of a Model 585 oscilloscope. The gate output from the 585 scope, in turn, triggers the laser power supply.

Previously, the ruby rod was directly cooled by flowing liquid nitrogen into the cavity. The direct cooling method was known to be effective in cooling the ruby rod and the flush lamp to near the liquid-nitrogen temperature; however, it was found difficult to control the temperature. Stable operation of a Q-switched laser requires a constant temperature. To obtain a constant temperature, an indirect cooling method was used, in which cold nitrogen gas ($\sim 170°K$) was directed into the cavity.

C. Band-Edge Modulator

Further experiments with SbSI were carried out using the setup described last month,[2] together with a light chopper between the light source and the interference filter. Comparison of the zero-field signal due to the chopper with the signal after application of an electric field to the crystal permitted calculation of the modulation index, m:

$$m = \frac{E_{max} - E_o}{E_{max}} \times 100 ,$$

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2. Monthly Contract Progress Report No. 2 (15 January 1965).

where E_0 is the signal due to the chopper, measured on the scope, and E_{max} is the signal with an applied electric field. $m \simeq 7$ percent for 250 volts dc; $m \simeq 3.5$ percent for 500 volts ac (peak to peak). The true modulation index is expected to be higher, since some light reaches the detector without going through the crystal. Response at higher frequencies was observed with the setup shown in Figure 1. This arrangement is capable of operating at frequencies up to 40 kc.

Figure 2 shows the crystal response at a 400-cps signal of 500 volts peak to peak. With the wave analyzer, response up to 20 kc was observed. This corresponds to a 40-kc crystal-response frequency, which is the limit of the present system. The change of the modulation index with frequency has not yet been determined, because the high resistance of the GaAs photodetector made its frequency response uncertain. An Si diode, as well as a small photomultiplier tube with S-1 response, will be used to determine the change of m as a function of frequency. The system will also be improved to permit measurements at higher frequencies.

D. Cesium Bulb

The cesium sources previously used for optical pumping in the MIROS program have deteriorated. Several new sources were prepared using argon as the buffer gas to avoid the strong 8952 Å line of xenon. This line is within the bandpass of the 8943 Å filter used in the experiments. The degree of RF excitation was strongly dependent upon the argon pressure. The best sources (25 percent pumping efficiency) had pressures around 1 mm Hg.

PRINCIPAL INVESTIGATORS' TIME DEVOTED TO WORK

The principal investigators assigned to the project and the time devoted to the work by these individuals from 20 December 1964 to 20 January 1965 are as follows:

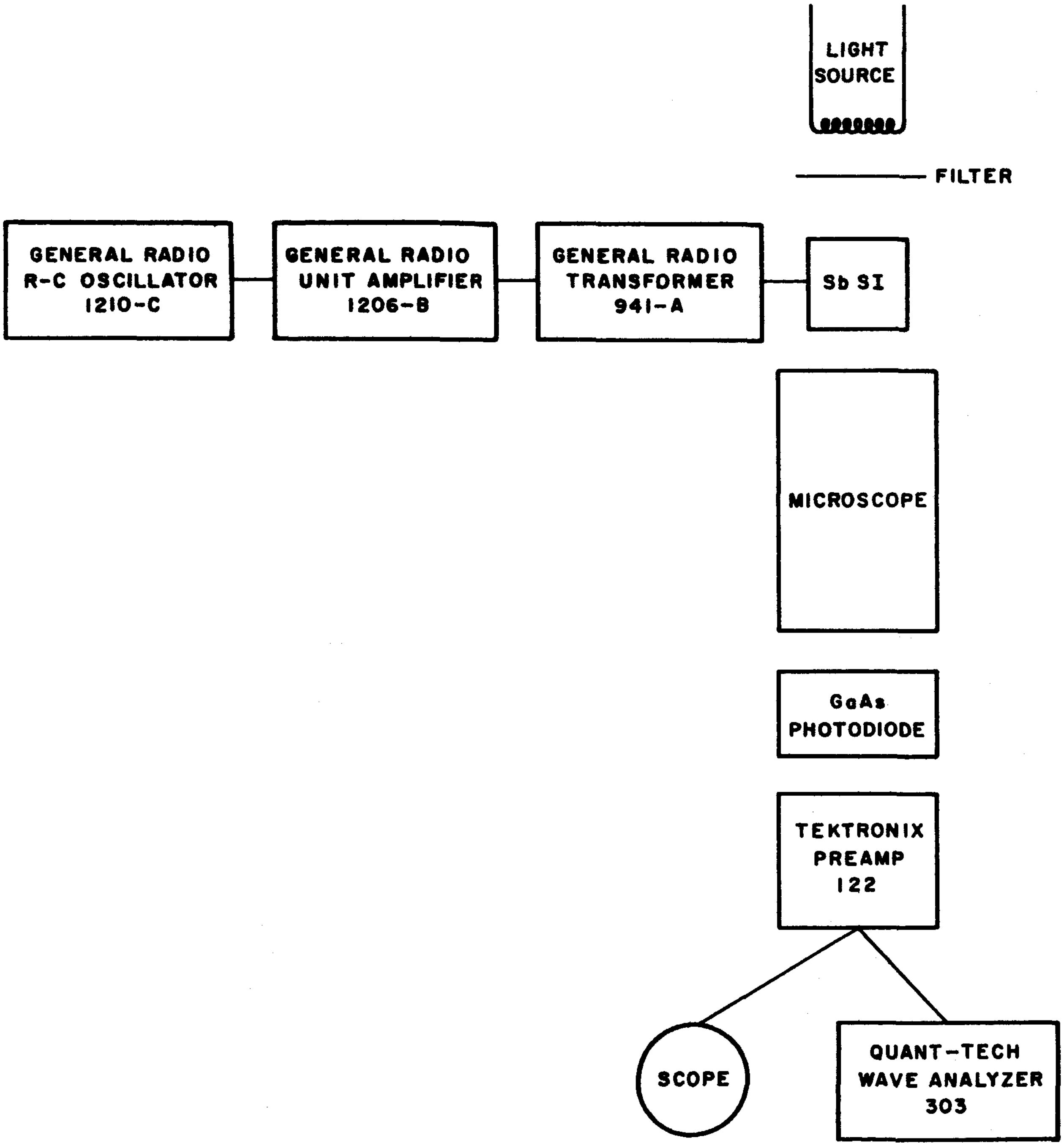

Figure 1. Experimental Setup for Observing Band-Edge Modulation

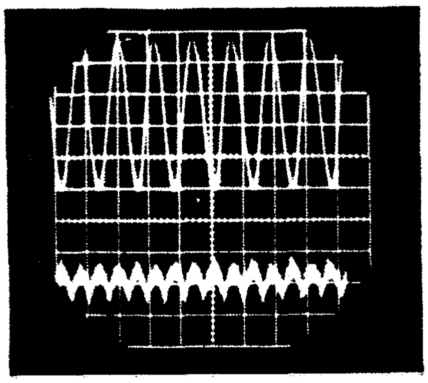

Figure 2. Oscillogram of the Crystal Response

Upper Beam (modulating signal)	Horizontal Vertical	= 2 milliseconds/cm = 100 volts/cm
Lower Beam (modulated light)	Horizontal Vertical	= 2 milliseconds/cm = 5 millivolts/cm

Personnel	Man-Hours
G. K. Chang	120
J. Powers	152
W. Haas	77.6
A. Varga	40
C. Wang	18
G. Racette	36
D. Cornelius	52
C. Doyle	38.6
P. Cholet	9.2

PLANS FOR THE NEXT INTERVAL

Continued effort will be devoted to generating Raman lasers and to fabricating GaAs injection lasers that are capable of pumping alkaline metal vapors. The modulation index, m, as a function of frequency will be determined.

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P. H. Cholet
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Approved:
M E Lasser
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