NBS TECHNICAL NOTE 987

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

A Servo Controlled Electro-Optic Modulator for cw Laser Power Stabilization and Control

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ERRATA TO ACCOMPANY NATIONAL BUREAU OF STANDARDS TECHNICAL NOTE 987, A SERVO CONTROLLED ELECTRO-OPTIC MODULATOR FOR CW LASER POWER STABILIZATION AND CONTROL, BY JOEL B. FOWLER, MICHAEL A. LIND AND EDWARD F. ZALEWSKI

CONSTRUCTION NOTES on Fig. 6 should read as follows:

1) BNC attached to 10Ω heater. Heater epoxied to back of detector close to center

2) Thermister 5K @ 25C heat sunk to back of detector

3) Cavity dimensioned for EG&G UV444B silicon detector

4) Use quartz oval < 0.5 mm thickness; wedged for best results

A Servo Controlled Electro-Optic Modulator for cw Laser Power Stabilization and Control

Joel B. Fowler, Michael A. Lind, and
Edward F. Zalewski

Center for Radiation Research
National Measurement Laboratory
National Bureau of Standards
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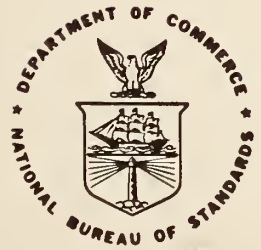

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Issued April 1979

National Bureau of Standards Technical Note 987
Nat. Bur. Stand. (U.S.), Tech. Note 987, 16 pages (Apr. 1979)
CODEN: NBTNAE

U.S. GOVERNMENT PRINTING OFFICE
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A SERVO CONTROLLED ELECTRO-OPTIC MODULATOR FOR cw LASER POWER STABILIZATION AND CONTROL

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Two simple designs for a low cost laser stabilization system are presented. The systems described are capable of stabilizing the power output of a cw laser line to better than .05% from DC to 100 kHz in the 350 to 1150 nm spectral range.

Key Words: *Laser power modulator; laser power stabilizer; photodetector characterization; radiometric instrumentation.*

INTRODUCTION

With the electro-optical crystals now commercially available it is possible to build a simple low cost system to extra-cavity stabilize the output of many cw lasers to better than .05% for stabilization bandwidths of DC to 100 kHz.[1,2,3][1] The systems currently employed at NBS to stabilize the laser beam power used for high accuracy characterization of detectors are described. Each system contains three main components: a low voltage electro-optic light modulator, a thermally stabilized silicon monitor detector and beam splitter assembly, and an electronics package to bias and servo-control the modulator crystal.

MODULATOR

Any one of a variety of electro-optic modulators can be used with the system. The choice of a device depends strongly on its intended application. The modulator used in the NBS system for stabilizing the laser power is a Lasermetrics [4] 3033 FW. This transverse field modulator was chosen primarily for its wide optical bandwidth, high maximum cw input power damage threshold, and relatively low, half-wave retardation voltage. The Appendix lists some of the more important specifications for the device.

---

*Present Address: Battelle, N.W., P.O. Box 999, Richland, WA 99352.

[1]Figures in brackets indicate the literature references at the end of this paper.

The crystals as supplied from the factory (see the Appendix) are surrounded by an index matching fluid and mounted in a 50.8 mm diameter cylinder that is 131 mm long excluding the polarizer. All windows in the unit are made from Dynasil grade fused silica and have a wideband MgF_2 coating to minimize interreflections. A Glan-laser polarizer is mounted at the exit port of the housing (with the provision to add an input polarizer when using unpolarized lasers).

ELECTRONICS PACKAGE

Two versions of this stabilizer system are currently in use at NBS. The circuit diagrams are shown in Figs. 1 and 2. Version 1 (Fig. 1) has been designed to include amplitude modulation capability and complete loop stability. Version 2 (Fig. 2) is designed for improved laser amplitude stabilization by sacrificing loop stability (oscillation may occur under certain operating conditions) and modulation versatility. The printed circuit board component layout is illustrated in Fig. 3 and the double-sided board layout suitable for photographic reproduction is given in Figs. 4 and 5. The same board is used for both systems with minor modifications for Version 2.

The electronics package has three main sections: a temperature controller to maintain a constant substrate temperature of the silicon monitor detector, a high gain servo-amplifier compensated to drive a particular detector/modulator system, and a high voltage amplifier to supply the necessary retardation voltages to the modulator.

In arranging the printed circuit board and the three power supplies within the electronics package, it is important to keep the ac power input well separated from the feedback control circuitry. To further minimize 60 Hz interference, the leads from the front panel BNC connections to the printed circuit board, especially the detector and thermistor inputs, should be as short as possible.

Since the temperature coefficient of the silicon monitor detector becomes non-negligible in the uv and ir spectral regions, it is necessary to control the temperature of the detector substrate to better than 0.1 °C if high dc stability is required.

The temperature of the silicon substrate is sensed with a thermistor (FENWAL GB41J1) [4] bridge circuit. A reference voltage in one leg of the bridge is adjusted by R31. The difference voltage is amplified by U1. The follower Q1 drives a resistance heater (MINCO HK610-0189.48)[4] attached to the back of the silicon detector. The temperature of the detector substrate is set a few degrees above the ambient temperature of the laboratory.

The silicon detector used in the NBS system (EG&G UV444B) [4] was selected for its high degree of uniformity and stability of response in the uv spectral region [5] and also for its large active area. The current output from this detector operated in a photovoltaic mode drives a current to voltage converter U3. The output of U3 must be kept below

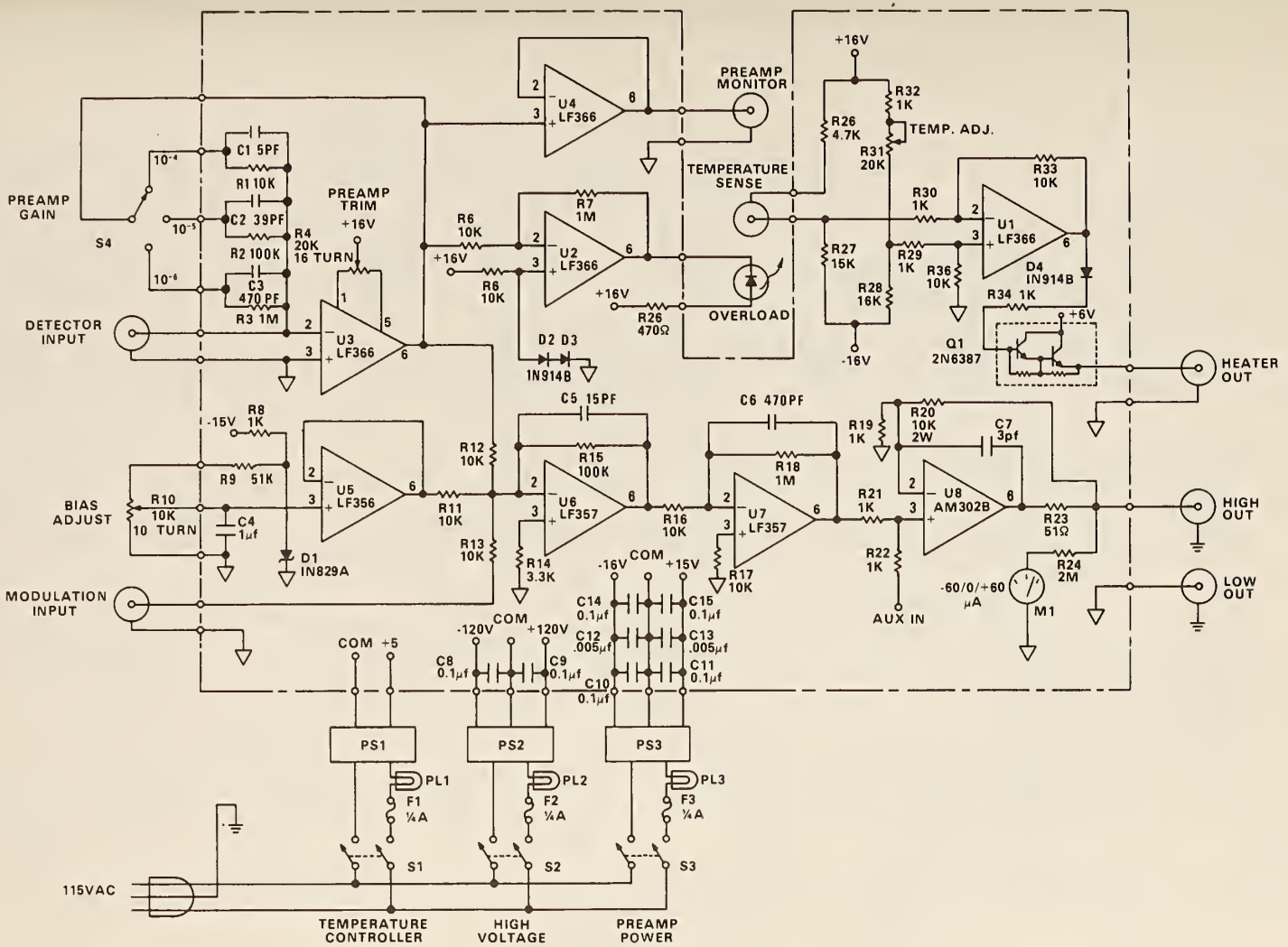

Fig. 1: Schematic diagram of laser stabilizer circuitry: Version 1.

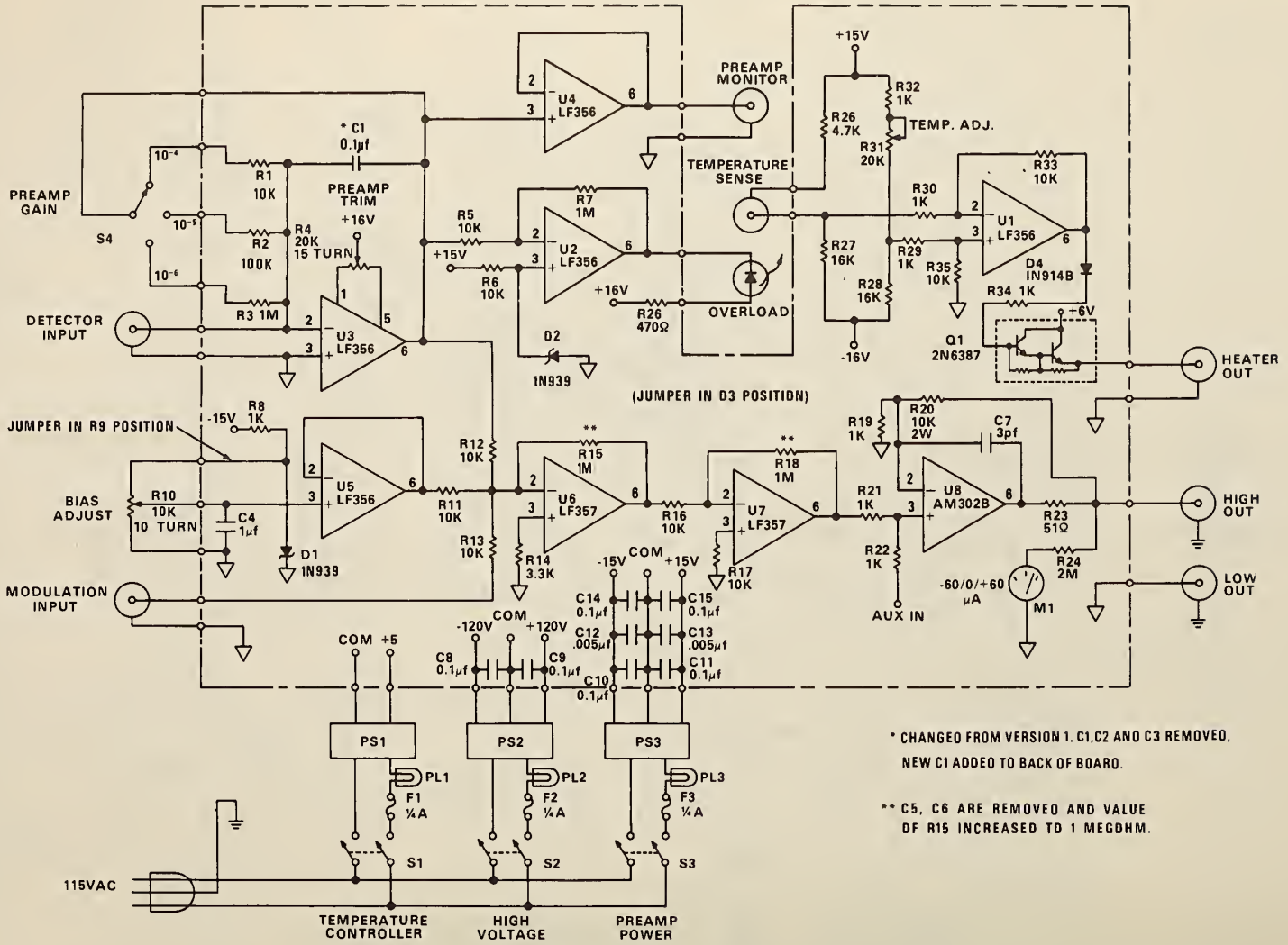

Fig. 2: Schematic diagram of laser stabilizer circuitry: Version 2.

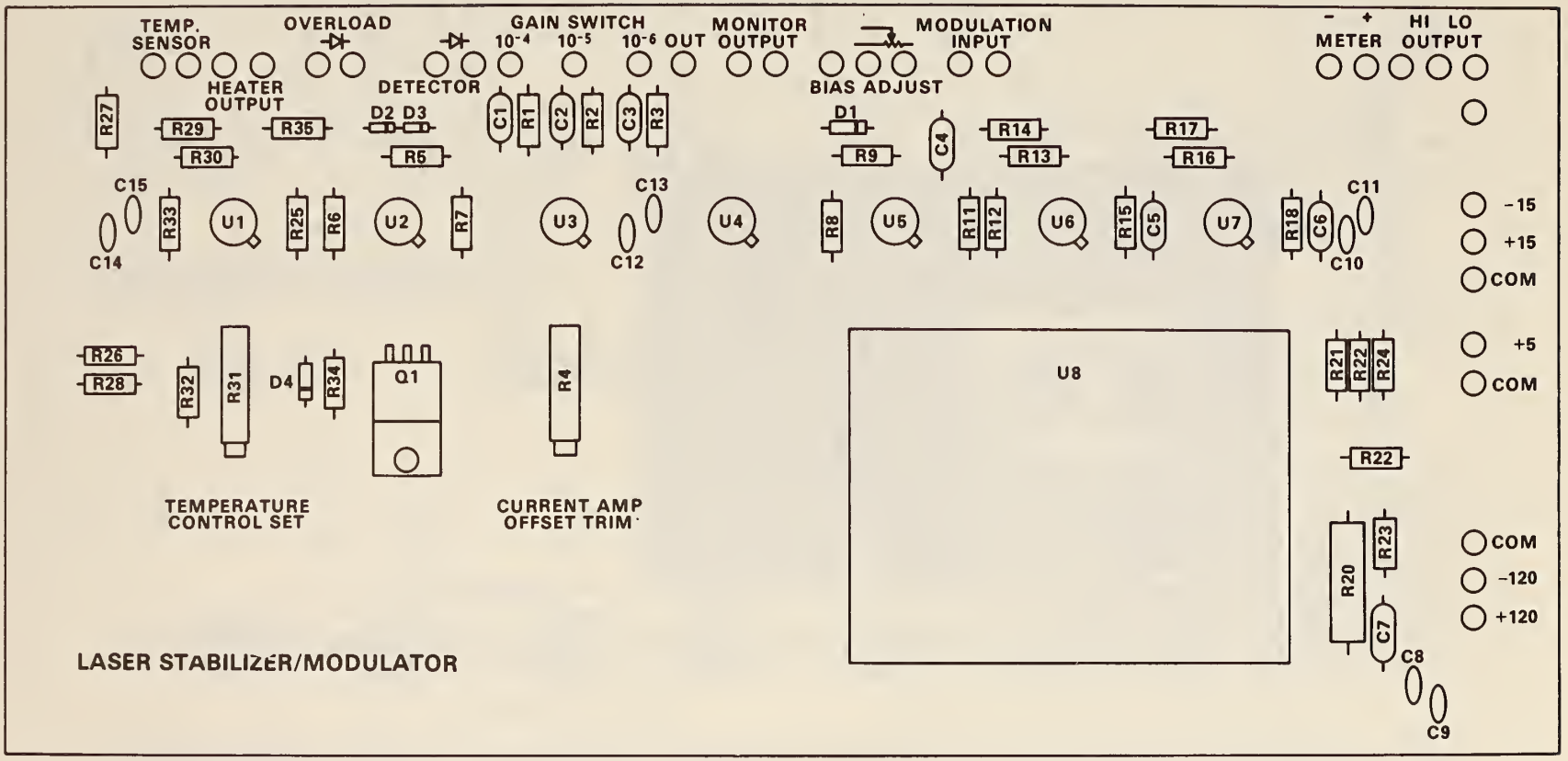

Fig. 3: Printed circuit board component layout.

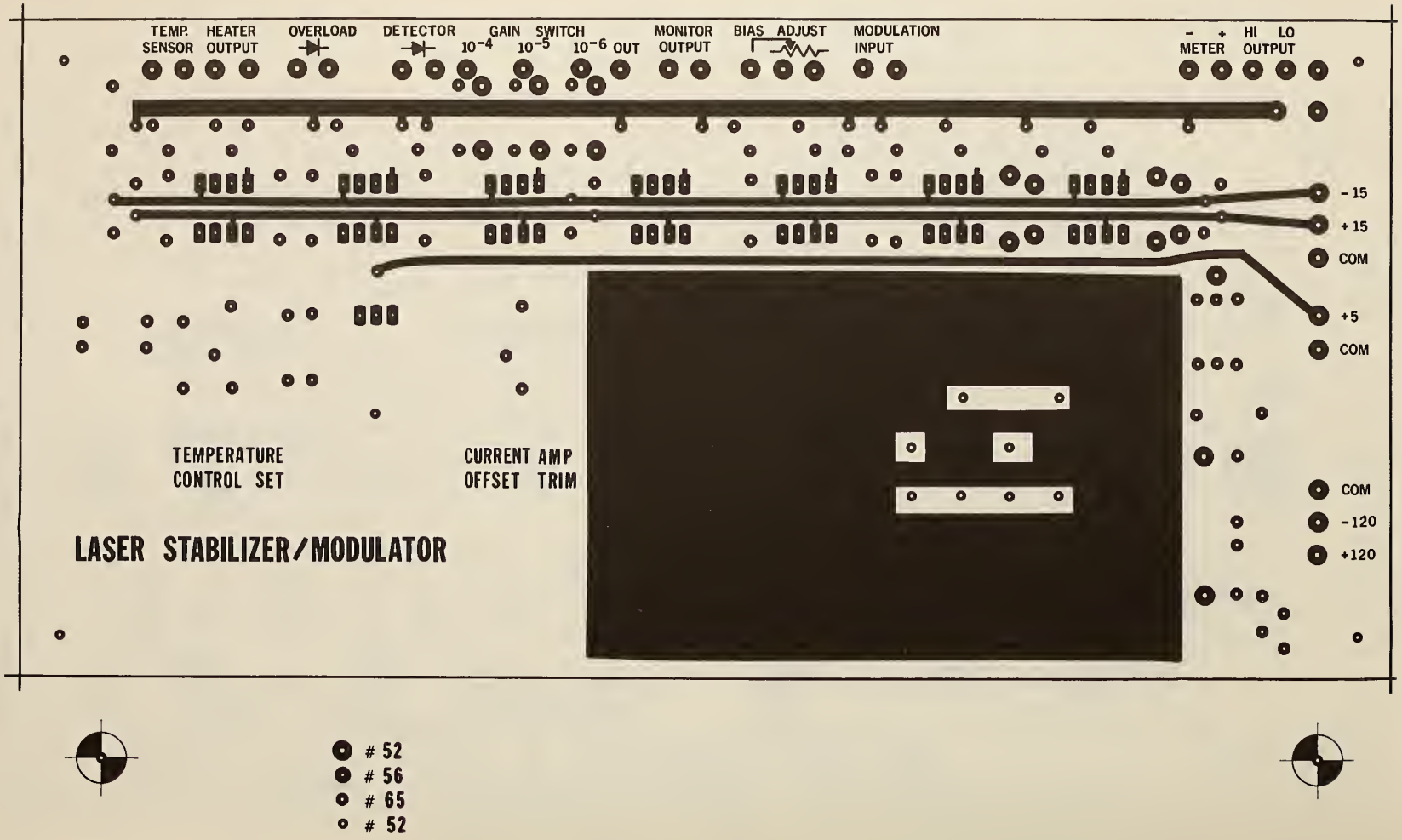

Fig. 4: Photographically reproducible printed circuit board layout: Side One

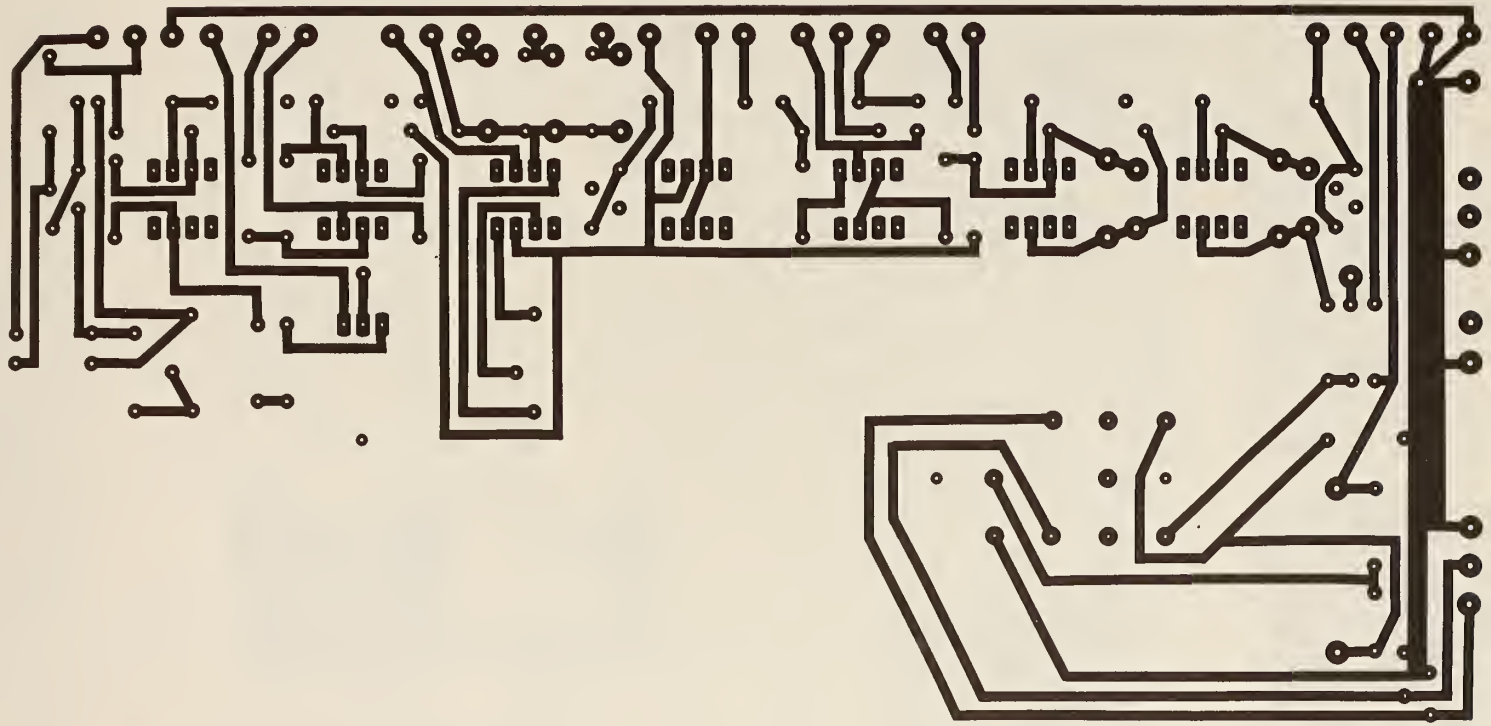

Fig. 5: Photographically reproducible printed circuit board layout:
Side Two

1.4 volts (9.0 volts for Version 1) to insure stability of the servo loop and help prevent clipping resulting in saturation. U2 detects any voltage over this value and lights an LED which signifies an OVERLOAD condition. A buffer amplifier for external monitoring of the preamp signal is provided by U4.

The output of the current amplifier is summed with an adjustable bias voltage via U6 and the external MODULATION INPUT connector. The sum of these three signals is amplified in U6 and U7 and fed into the high voltage, wide-bandwidth amplifier U8 (DATEL SYSTEMS AM302B or AM303B) [4]. This signal is then used to drive the modulator.

The bandwidth of the Version 1 system is dependent primarily on the preamp gain. Depending on the type of modulator used, the system bandwidth varies from about DC to 10 kHz at the 10^{-6} A/V setting and from DC to approximately 100 kHz at the 10^{-4} A/V setting. The bandwidth of Version 2 is higher but is not totally protected from instability (due to the higher loop gain) necessitating the use of an oscilloscope to monitor the high gain stages. Version 2 is the most versatile and could actually have a variable gain in the 2nd stage (U7) higher than the standard 100 in some applications. The printed circuit board has been laid out to allow easy access to the critical components that control the servo gain characteristics. The component values shown in the schematic diagram for the Version 1 design have been chosen to provide a maximum flat transfer characteristic from the MODULATION INPUT to the detected laser power when using the modulator crystal described above. If another modulator crystal is used it may be necessary to modify these values somewhat to achieve a flat response curve. The transfer characteristic for the Version 2 circuit is not necessarily flat since it was designed primarily for laser stabilization [6]. Although the higher system gain results in a tighter servo action the possibility of instability will exist.

DETECTOR AND BEAM SPLITTER ASSEMBLY

The beam splitter and detector housing is shown in Fig. 6. The beam splitter itself is a quartz oval, wedged slightly to minimize the effects of interference bands. The oval should be as thin as possible for the least beam deflection at the exit port of the housing. The recess at the entrance port of the assembly is to accommodate an iris diaphragm or a precision aperture. The silicon detector is mounted in the recessed portion of the removable cover plate. The heater and thermistor are cemented to the back of the detector for the best temperature control.

OPERATION OF THE SYSTEM

The first step in the operation of the system is to place the modulator in the laser beam, preferably near the laser itself, and then align it. During the alignment procedure the power level of the incident laser beam should not exceed 100 milliwatts in order to avoid damage to the crystal. The modulator should be rigidly mounted after

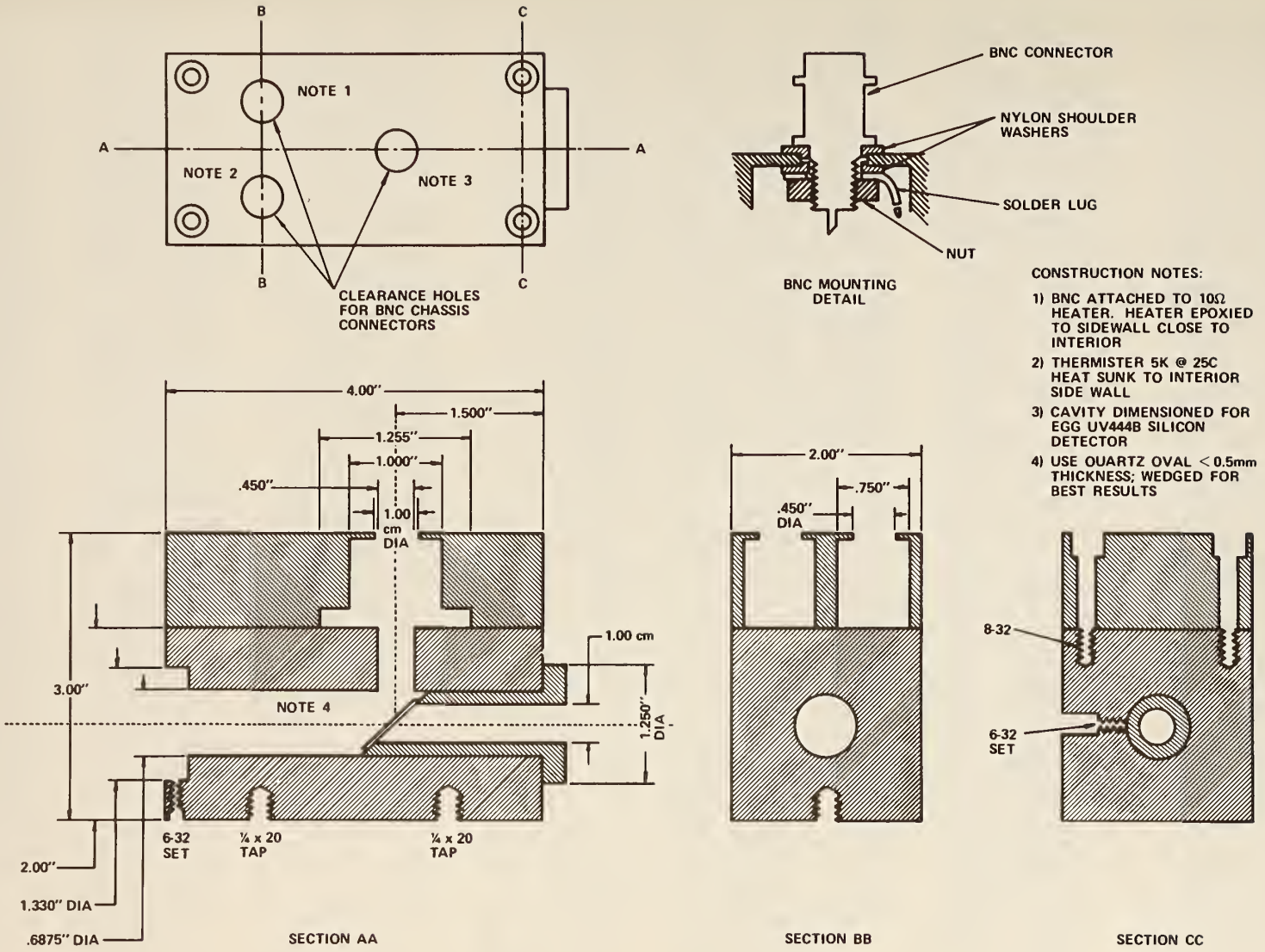

Fig. 6: Mechanical drawings of beam splitter and detector housing.

the beam is centered in both the front and rear apertures of the device. As with most transverse field modulators, the crystal should be oriented at 45° with respect to the incident polarization vector to obtain the maximum contrast ratio. The integrally mounted Glan-laser polarizer is then locked into position at ±45° with respect to the edge of the crystal (in some stabilization applications other angles may be more suitable).

The beam splitter assembly should be placed into the beam as far down the optical path as is feasible. The best stability is obtained from the system when there are no optical elements in the beam after the beam splitter housing. The reflected beam from the quartz plate should be perpendicular to the polarization of the incident beam; e.g. for a vertically polarized beam the reflected beam should be in the horizontal plane.

The HEATER OUT, TEMPERATURE SENSE and DETECTOR are connected to the beam splitter assembly via BNC cables. The length of these cables should be kept to a minimum to minimize noise pickup. The modulator is connected to the HIGH and LOW OUTPUTS of the electronics package by two more BNC cables. In order to insure that the capacitive load of the modulator does not destroy the high voltage driver amplifier in the electronics package, it is recommended that a 1 MΩ resistor be placed across the modulator leads as close as possible to the modulator itself.

Turn on the TEMPERATURE CONTROLLER and allow a few minutes for the temperature of the silicon detector to stabilize. At the same time warm up the preamplifier and servo electronics by turning the PREAMP switch on. The HIGH VOLTAGE should be activated only when control of the beam power is desired. The detector may be monitored at the MONITOR output whenever the PREAMP switch is on.

Adjust the laser to the desired operating range not exceeding the maximum of 15 watts specified for the modulator. Turn the PREAMP GAIN control to the most sensitive position possible without the OVERLOAD indicator lighting. It may be necessary to insert some kind of neutral density filter between the detector and the beam splitter at high power levels. In the visible spectral region several layers of white paper make a satisfactory attenuator.

After the HIGH VOLTAGE is turned on, adjust the BIAS OUTPUT so that the meter remains somewhere within its operating range. If a suitable operating point cannot be found, then switch the HIGH and LOW outputs leading to the modulator. The BIAS ADJUST controls the dc bias on the modulator which in turn regulates the power transmitted through the polarizer.

It is possible to inject a waveform into the MODULATION INPUT and thereby modulate the laser beam. It may be necessary to adjust the amplitude of the input signal and the BIAS ADJUST to avoid clipping of the waveform.

In applications requiring stabilizing laser beams outside of the spectral bandpass of the modulator such as frequency doubling experiments, it is necessary to place the modulator in the beam of the pump laser and the monitor detector in the doubled beam. The best stability from a dye laser output is also achieved by modulating the pump laser beam and monitoring the output beam.

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[2] R. L. Barger, J. B. West and T. C. English, Appl. Phys. Lett. 27, 31 (1975).

[3] J. Geist, M. A. Lind, A. R. Schaefer and E. F. Zalewski, NBS Technical Note 954, 1977 (U.S. Government Printing Office, Washington, D. C. 20402, SD Cat. No. C13.46:954).

[4] The use of trade names in this paper in no way implies endorsement or approval by NBS and is included only to define the procedure.

[5] M. A. Lind and E. F. Zalewski, Appl. Opt. 15, 1377 (1976).

[6] J. B. Fowler, Proc. of the Electro-Optics and Laser Conference (Indust. and Sci. Conf. Mgmt., Chicago, 1977) p. 690.

APPENDIX

Specifications of Modulator Used

Crystal material	AD*P
Number of crystals	4
Square aperture	2.5 mm
Maximum transmittance	95%
Useful optical bandwidth	340-1200 nm
Useful electrical bandwidth	DC-100 MHz
Maximum cw laser input laser	15 W
Half-wave retardation voltage	
@ 488 nm	135 V
@ 515 nm	142 V
@ 633 nm	175 V
Typical capacitance	125 pf

NBS-114A (REV. 9-78)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS TN 987	2. Gov't. Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

A Servo Controlled Electro-Optic Modulator for cw Laser Power Stabilization and Control

5. Publication Date April 1979

6. Performing Organization Code

7. AUTHOR(S)

Joel B. Fowler, Michael A. Lind, and Edward F. Zalewski

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

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10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

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