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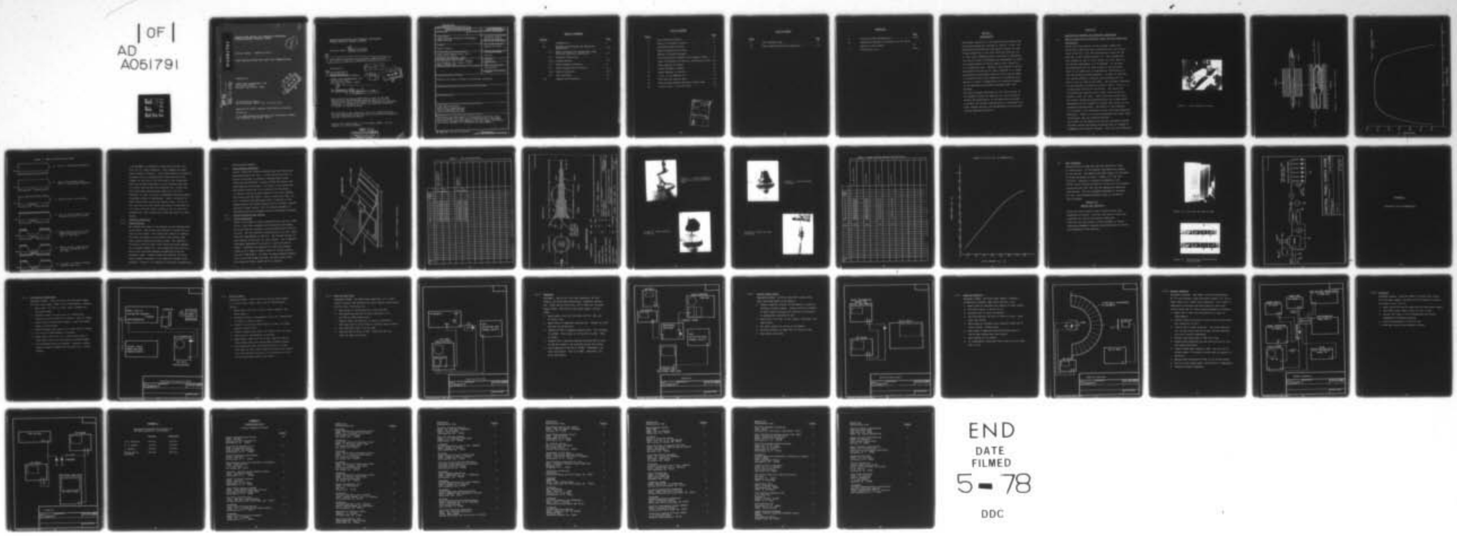

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MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING PROGRAM QUARTERLY TECHNICAL REPORT

Contract Number DAAB07-76-C-8135

LIGHT EMITTING DIODES FOR FIBER OPTIC COMMUNICATIONS

Prepared By:

LASER DIODE LABORATORIES, INC.
205 Forrest Street
Metuchen, New Jersey 08840

Third Quarterly Report
for the Period 1 April 1977 to 30 June 1977

Approved for public release; distribution unlimited.

Placed by:

U. S. Army Electronics Research and Development Command
Fort Monmouth, New Jersey 07703

MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING PROGRAM QUARTERLY TECHNICAL REPORT

(15) Contract Number DAAB07-76-C-8135

(6) LIGHT EMITTING DIODES FOR FIBER OPTIC COMMUNICATIONS

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Prepared by:

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Product Development Manager

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205 Forrest Street
Metuchen, New Jersey 08840

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This project has been accomplished as part of the Army Manufacturing and Technology Program, which has as its objective the timely establishment of manufacturing processes techniques or equipment to insure the efficient production of current or future programs.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The design and fabrication of high speed etched-well light emitting diodes for fiber optic communications is discussed with regard to materials synthesis via LPE, wafer fabrication, and device assembly in a manufacturing environment.

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SECTION I

INTRODUCTION

The primary objective of this Manufacturing Methods and Technology Engineering Program is twofold. First, the manufacturing methods and techniques necessary for the volume production of the light emitting diode for use in fiber optic communications as outlined in Specification SCS-511 must be developed and implemented to insure the highest degree of device quality and reliability at a reasonable cost. Secondly, verification of device performance and quality for LED's produced in a volume manufacturing environment must be carried out by means of rigorous testing and evaluation in accordance with SCS-511 in order to demonstrate the technical adequacy of the manufacturing methods developed under this contract.

The major program objectives for the third quarter of the program include the addition of a zinc diffusion process and modification of the photo-resist process to produce low forward voltage devices, construction of fiber coupled devices, and documentation of electrical testing required by SCS-511.

SECTION II

MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING

2.1 Wafer Processing for Etched Well Light Emitting Diode Chip Fabrication.

During the third quarter of the program, etched well diodes were fabricated which essentially met the requirements of SCS-511. The one characteristic which has not been met is the forward voltage, V_f. This voltage has been running in the 2-3 volts range, at 20 ma, where as the SCS-511 requirement is 1.9V maximum. It has been determined that the 'p' side contact to the epitaxial wafer is not ohmic and is contributing significantly to the high forward voltage observed. In order to overcome the contact problem, a shallow zinc diffusion will be done on the 'p' side of the wafer. The equipment assembled for this process is shown in Figures 1 and 2. Figure 3 is a temperature profile of the furnace. The relatively low temperature together with a short time period will produce a thin 'p+' skin. These conditions should leave the surface unaffected morphologically and no additional processing will be required to prepare the surface for the succeeding process steps. The affect of the diffusion is to produce a low resistance contact with good mechanical adherence. Figure 4 is a wafer processing flow chart which incorporates the zinc diffusion process.

As a result of the addition of the zinc diffusion process, the photo resist and masking processes must be changed to accommodate the sequence changes. After the zinc diffusion,

Figure 1. Zinc Diffusion Furnace.

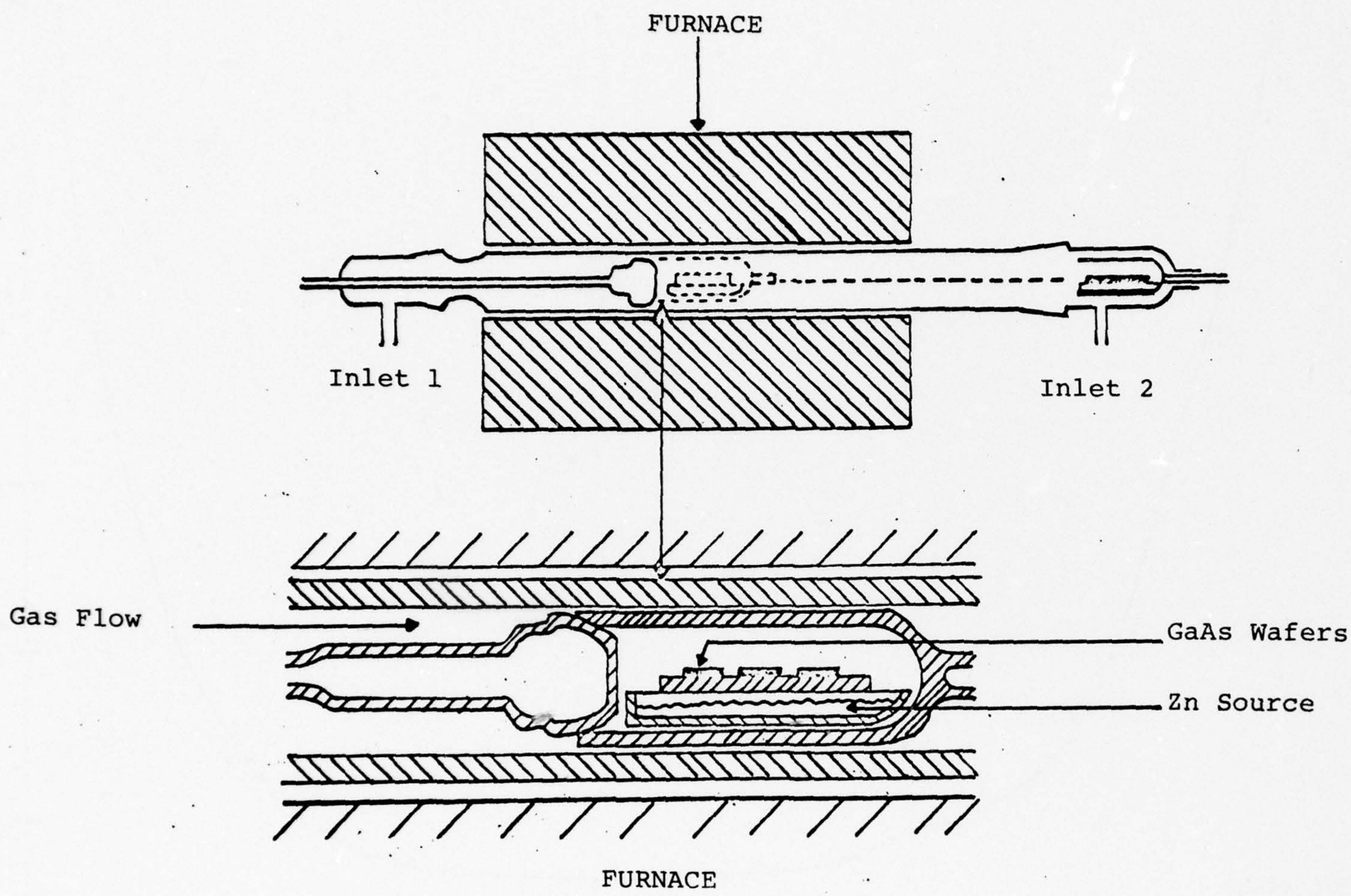


Figure 2. Detail of Diffusion Furnace.

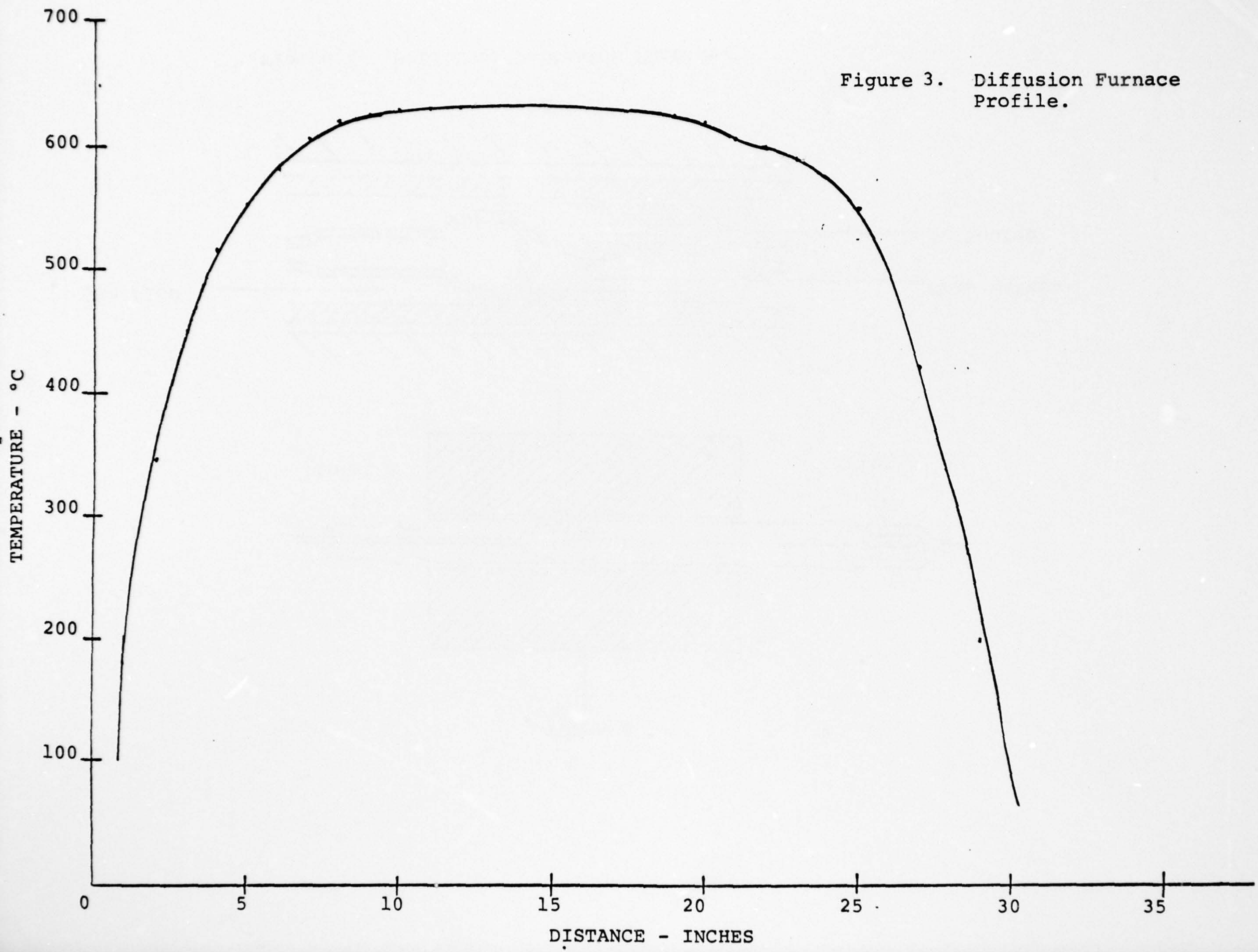
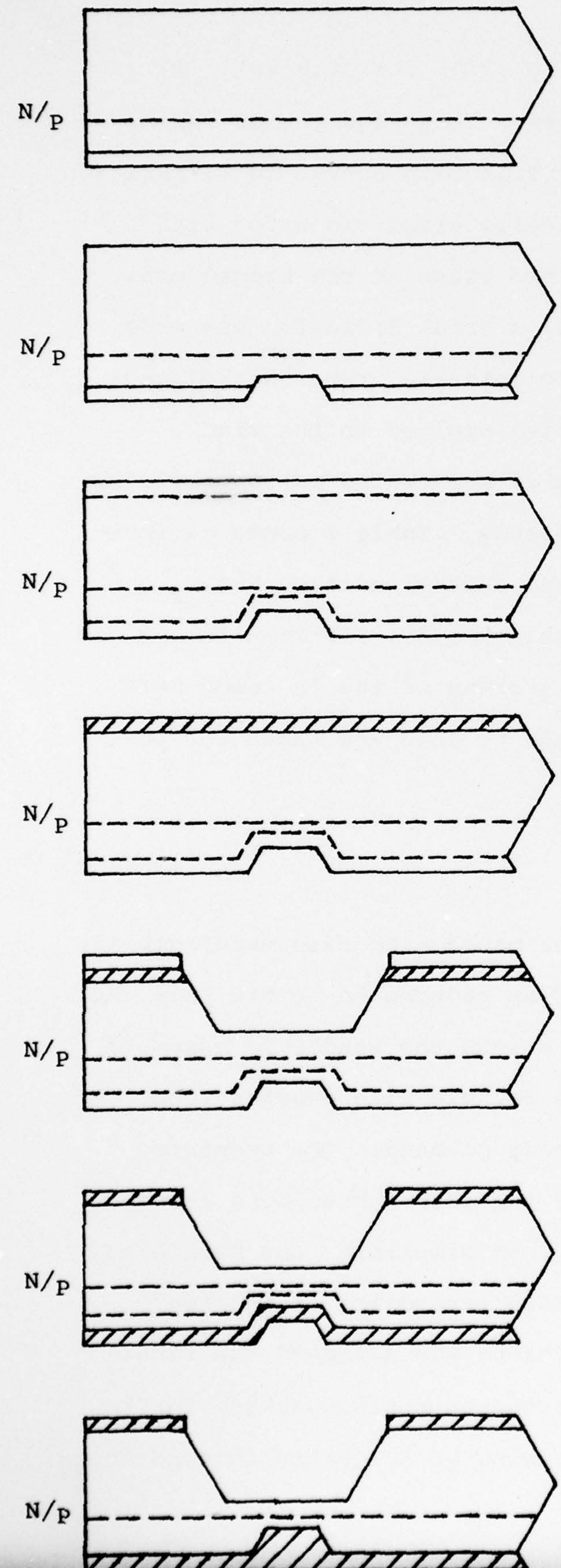


Figure 3. Diffusion Furnace Profile.

Figure 4. Wafer Processing Flow Chart



a) Coat 'p' side with photoresist.

b) Expose and develop resist, etch 'p' side contact aperture.

c) Remove resist, zinc diffuse.

d) Lap 'n' side to remove p skin, evaporate AU-GE on 'p' side.

e) Apply photo resist to n side. Expose and develop resist, etch 'n' side well.

f) Remove resist, evaporate CR, platinum, palladium, AU on 'p' side.

g) AU plate 'p' side to produce integral heat sink.

a re-alignment is required to align the etch well dot with the 'p' contact aperture. This requires an index stop as shown in Figure 5. This stop serves to re-position the wafer so as to automatically align the wafer with respect to the dots on the two sides of the hinged mask. Using the process described, a trial diffusion was made on a wafer from the Bur-B-28 epitaxial run. Nickel and gold electroless platings were applied to the zinc diffused 'p' side, in place of evaporated layer previously described, purely for expediency. Table I contains forward voltage data on test and control units. The V_f on the test units are well within the SCS-511 requirement of 1.9 V max. at 20 ma. Under etching of the 'n' side well degraded the light output and no data was taken for power output.

2.2 Packaging Technology

2.2.1 Package Design.

Two changes were made in the package to ease manufacturing of the parts. The Ferrule was reduced in length from one inch to 0.75 inches. This allows the vendor to assemble the fiber and sheath in the ferrule with greater ease using simple fixturing already on hand. The segmented cut-outs in the face end of the sleeve have been changed to a straight across cut. This simplifies the machining while still providing adequate straddling of the two connector leads. Neither change has affected the final diode assembly technique or the essential package configuration. Figure 6 is a drawing of the parts incorporating the described changes.

2.3 Diode Assembly Technique

Figure 7 shows the fiber protruding from the ferrule and positioned within the well. At this point the fiber is further positioned to produce a maximum power output reading on the detector. Figure 8 shows the sleeve with epoxy applied to its edges. In figure 9, the sleeve has been moved forward and is in contact with the header. In Figure 10 epoxy has been applied to the joint between the ferrule and the sleeve. After a short cure time, the unit is removed and additional epoxy is applied at the header-sleeve, and ferrule-sleeve joints to effect complete sealing of these joints. The illustrated assembly is performed using the alignment fixture previously described.

2.4 Device Evaluation and Testing

2.4.1 Device Evaluation

Table II list data on fiber coupled devices from Lot # BUR-B-20-2. The fiber assembly was constructed from sample parts and does not conform to the finished device outline as such. The two essential characteristics, P_o and λ peak meet the requirements of SCS-511. The forward voltage is high because of the poor 'p' side contact. Lot # BUR-B-28 previously described in section 2.1, with the data of Table I, indicates the approach to lower the voltage. Figure 11 is a graph of power output vs. device current for Lot # BUR-B-20-2. In order to reduce heating effects due to the high forward voltage, the units were driven by a pulse of 800 ns width and 45 μs period.

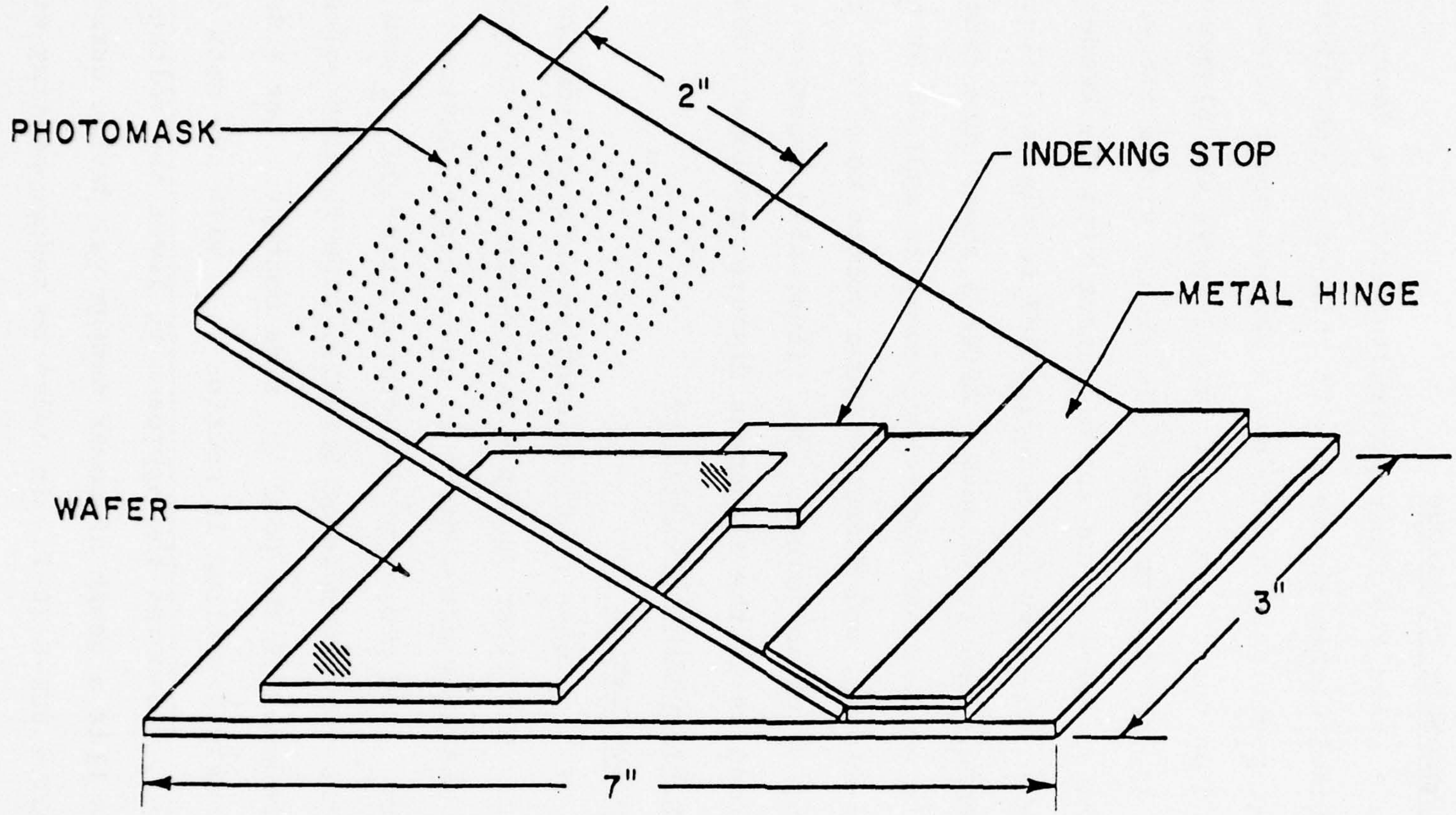


Figure 5. Sketch of Hinged Photomask.

TABLE I. Zinc Diffusion Test

		Zinc Diffusion Test BUR-B-28			Control BUR-B-20								
		V_f 20 ma	V_f 100ma		V_f 20 ma	V_f 100ma							
DATE													
TIME													
No.													
1		1.70	2.10		2.60	4.00							
2		1.70	2.30		2.50	3.60							
3		1.65	2.00		2.50	3.60							
4		1.10	1.50		2.60	3.90							
5		1.70	2.20		2.60	3.90							
6		1.20	2.00		2.80	3.90							
7		1.80	2.50		2.50	4.00							
8		1.75	2.40		2.80	3.90							
9		1.65	2.00		2.80	3.90							
10		1.65	2.00		3.00	4.00							
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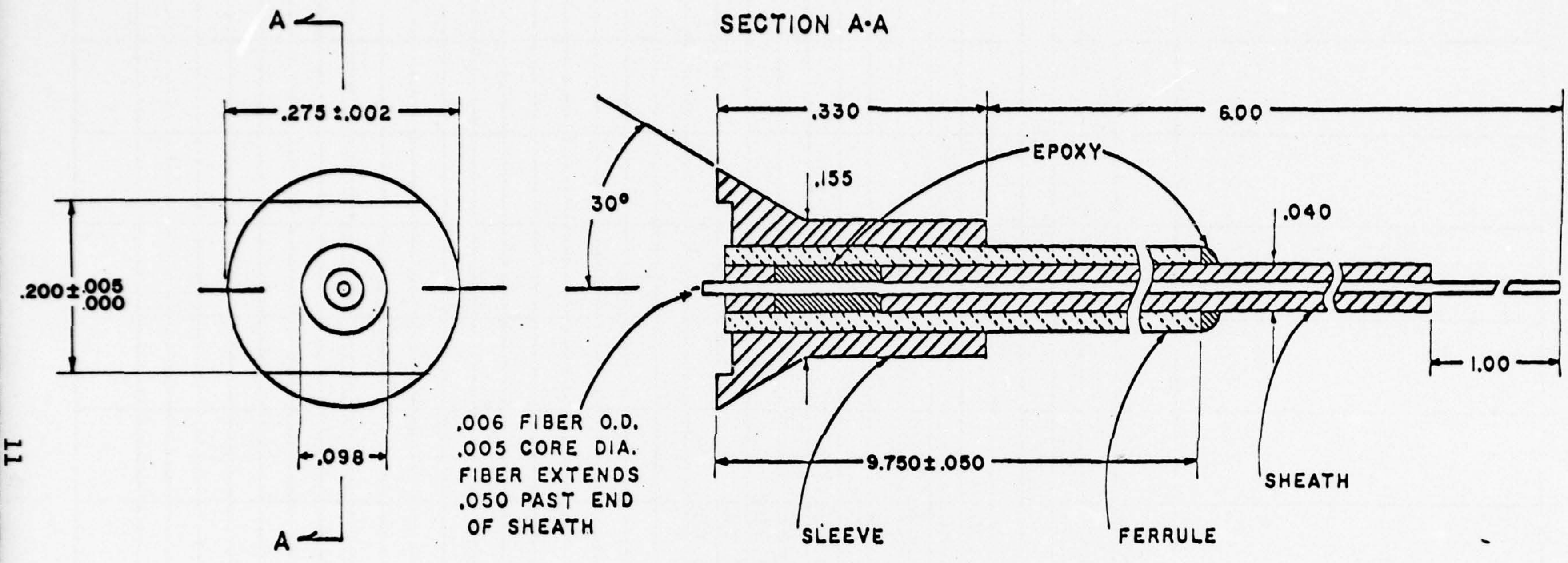

FIBER CHARACTERISTICS

CHARACTERISTICS	MIN.	MAX.	UNIT
ATTENUATION (AT λP) (8200Å)	–	50	db/km
CORE DIAMETER	–	125	um
CLADDING DIAMETER	150	–	um
PROTECTIVE JACKET DIAMETER	1	–	mm
NUMERICAL APERTURE (N.A.)	–	0.3	–
TENSILE STRENGTH	50	–	NEWTONS
BENDING RADIUS	1.5	–	mm

LDT 177 FIBER ASSEMBLY

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Figure 6. LED Fiber-Ferrule Assembly with Support Sleeve.

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Figure 7. Fiber Protruding from Ferrule, Positioned in Well.

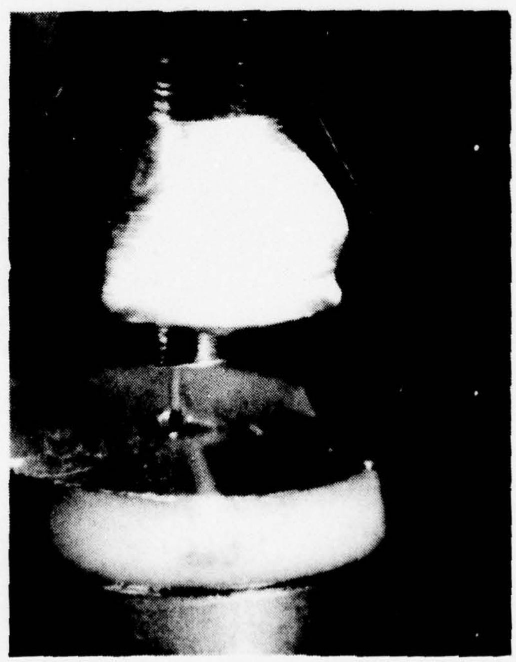

Figure 8. Epoxy Applied to Sleeve.

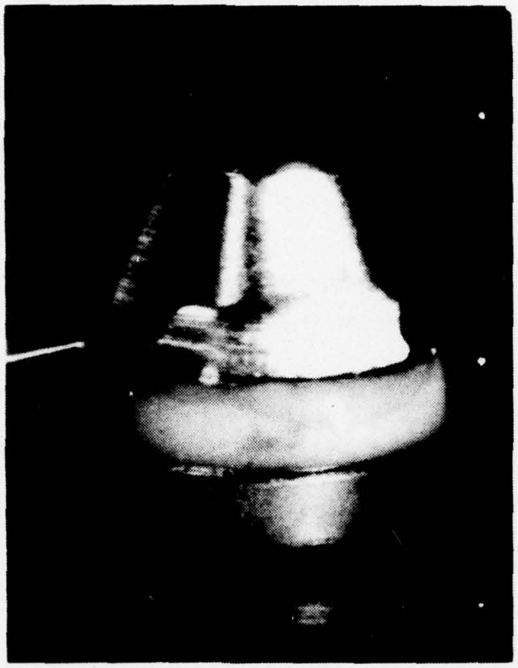

Figure 9. Sleeve Epoxied to Header.

Figure 10. Sleeve Epoxied to Ferrule.

TABLE II FIBER COUPLED DEVICES LOT BUR-B-20-2

		P_o (mw) @ 100 ma		λ peak (nm)		V_f @ 20 ma		V_r @ 10 μa					
DATE													
TIME													
No.													
1		.485		802		2.5		12					
2		.520		810		2.3		8					
3		.523		817		2.6		10					
4		.501		805		2.5		9					
5		.498		810		2.5		8					
6		.385		808		2.8		9					
7		.532		798		3.0		12					
8		.555		803		2.7		10					
9		.600		806		2.4		11					
10		.542		803		2.5		4					
Avg.		.525		805		2.5		9.3					
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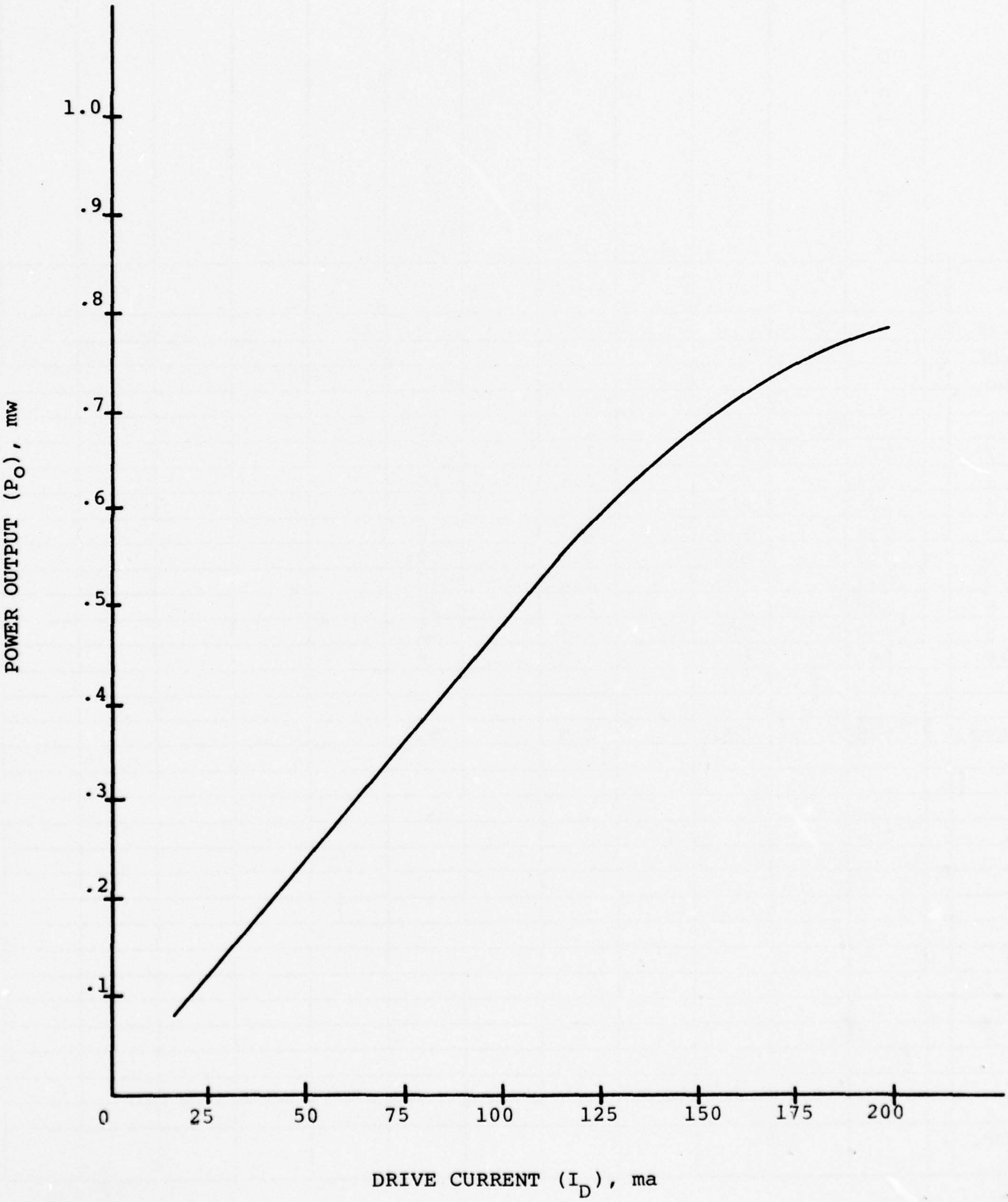
Figure 11. P_O vs. I_D Lot #BUR-B-20-2.



2.5 Test Equipment

Figures 12 and 13 show the life test and burn-in rack in construction. At the present time there are sockets for 60 devices. The cabinet and power supply are designed to house and power 150 units. Figure 14 is the rack circuitry. Appendix A contains a breakdown of the various tests required by SCS-511, along with the equipment connections for each test and the appropriate operating instructions. All the equipment described is available for use. The paragraph headings refer to the SCS-511 test paragraph.

SECTION III

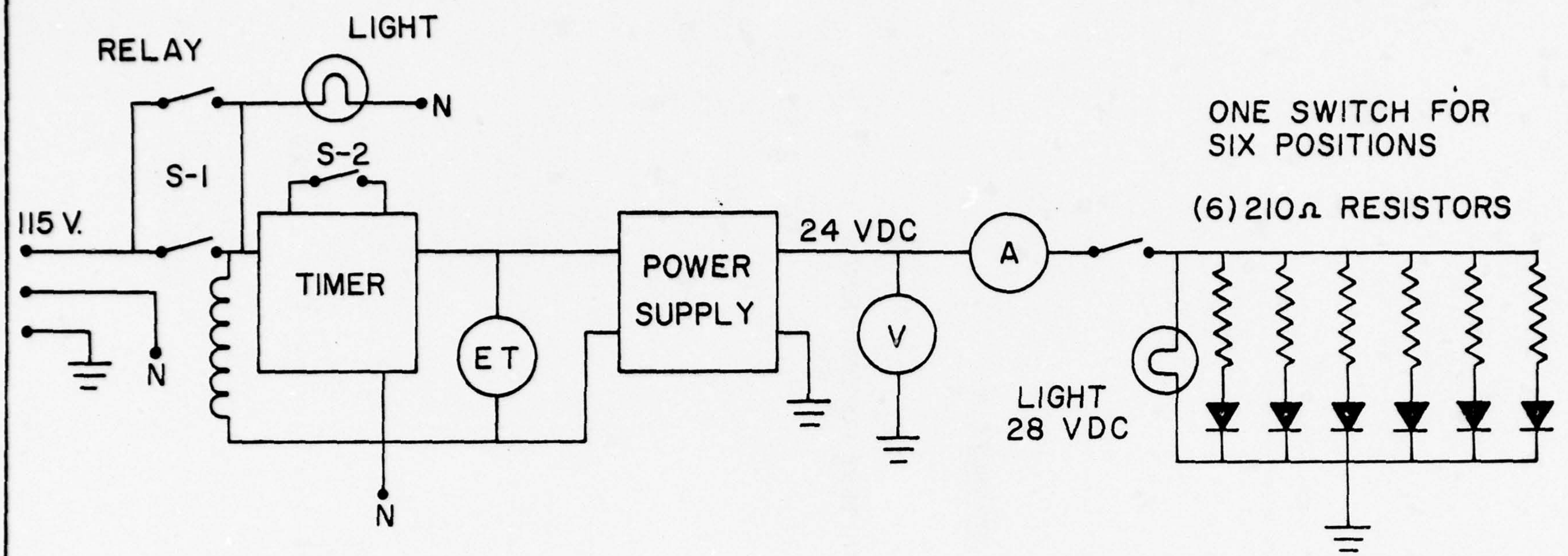
SUMMARY AND CONCLUSION

During the third quarter fiber coupled devices were assembled and tested. Life-test and Burn-in racks were completed and testing procedures established.

Plans for the next quarter include assembly of second engineering samples, complete characterization of devices and beginning of life testing.

Figure 12. Life Test and Burn-In Rack

Figure 13. Rack Close-Up Showing Devices on Heat Sinks.



CONTROL PANEL-BURRIS DIODE

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Figure 14.

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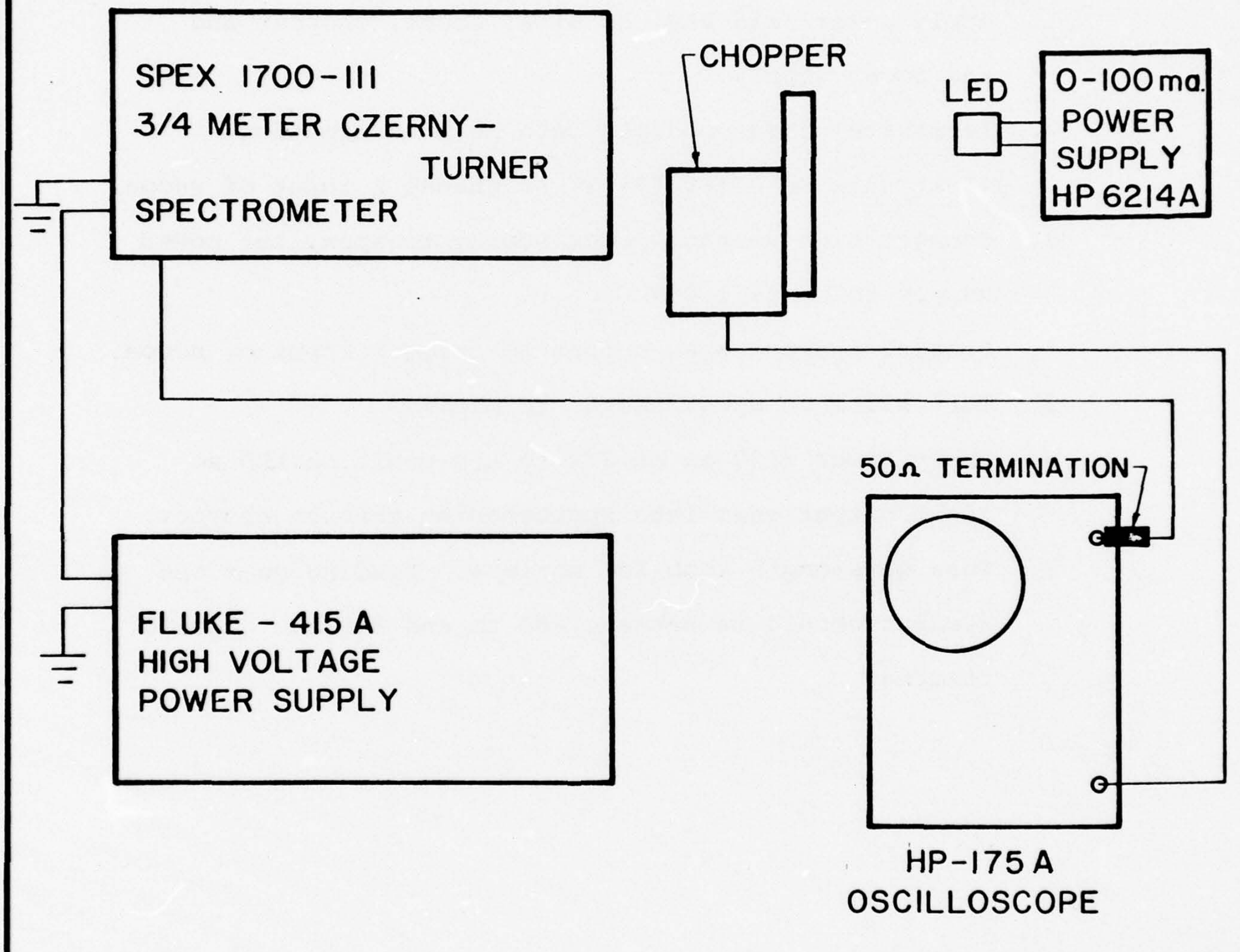
APPENDIX A

ELECTRICAL TEST DOCUMENTATION

4.6.4 Peak Emission Wavelength

Equipment needed: Fluke 415A high voltage power supply, HP 6214A power supply, Spex 1700-11 Spectrometer, Chopper.

1. Apply power (115 VAC) to 415A, scope, chopper and and power supply.
2. Terminate output of spex into 50 Ω termination (Tektronix pn 011-0049-01) at Chanel 1 input of scope.
3. Connect high voltage power supply to spex, set power supply to minus 1000V.
4. Connect chopper sync output to trigger input of scope.
5. Turn slits on spectrometer to minimum.
6. Apply power (100 ma at 2V) to LED position LED so light output goes into spectrometer through chopper.
7. Turn wavelength knob for maximum. Reading on scope reading should be between 800 nm and 830 nm. Record reading.



Wavelength and Spectral Width.

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4.6.5 <u>Spectral Width</u>

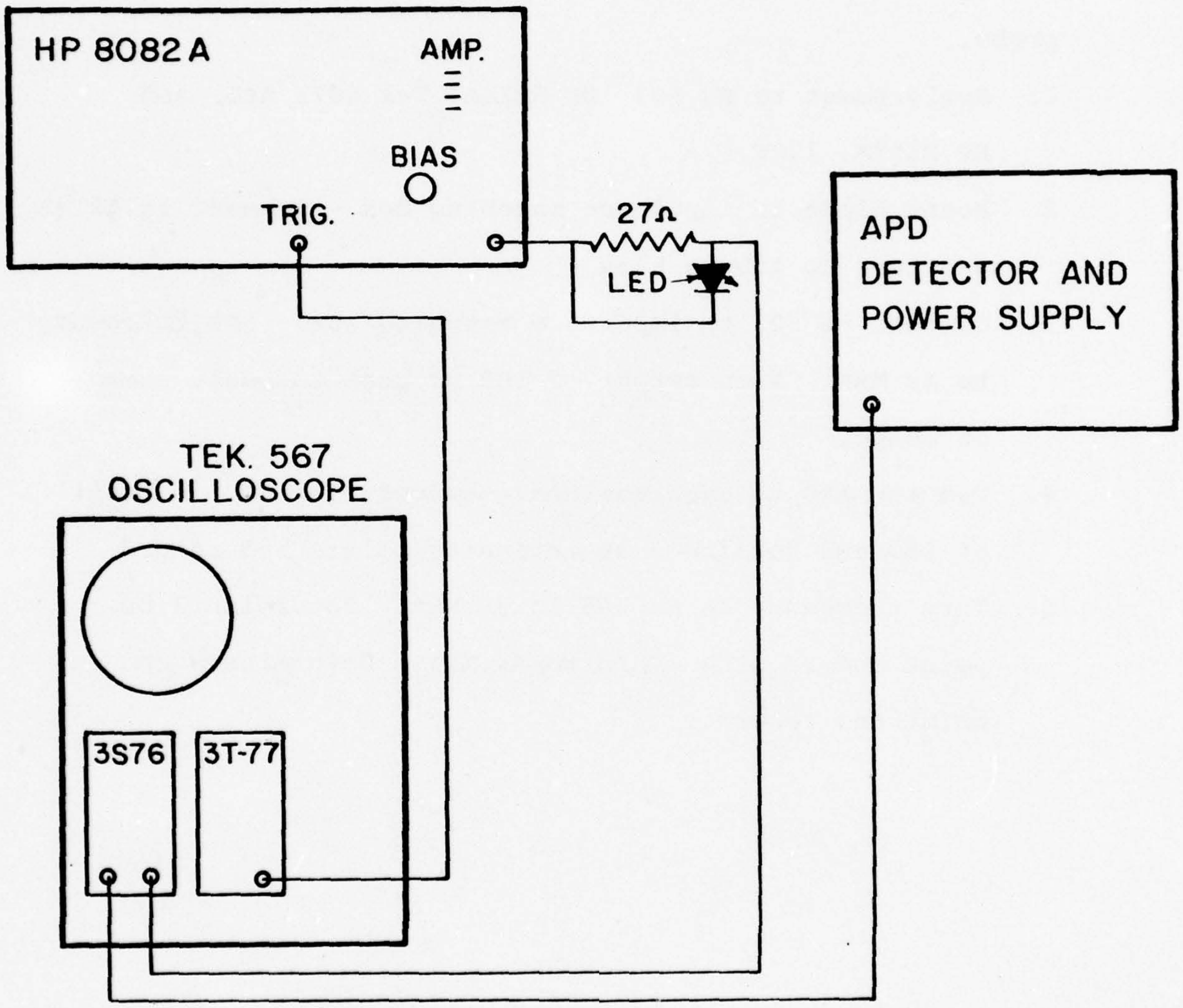
Equipment needed: Fluke 415A high voltage power supply, H. P. 6214A power supply, Spex 1700-111 Spectrometer, Chopper.

1. Apply power (115 VAC) to 415A, scope, chopper, and power supply.
2. Terminate output of spectrometer into 50 Ω termination at Chanel 1 input of scope.
3. Connect high voltage power supply to spex, set power supply to minus 100V.
4. Connect chopper sync output to trigger input of scope.
5. Turn slits on spectrometer to minimum.
6. Apply power (100 ma at 2V) to LED, position LED so light output goes into spectrometer through chopper.
7. Turn wavelength knob for maximum reading on scope, turn knob for 50% of peak amplitude reading and record. Turn knob opposite direction, go through peak to 50% of peak amplitude reading and record.

4.6.6 Rise and Fall Time

Equipment needed: HP 8082A *pulse generator*, 27 Ω 1 watt carbon resistor, APD detector and power supply, oscilloscope Tek 567 3576, 3T77A plug ins.

1. Apply power to pulse generator, scope and APD.
2. Turn amplitude and bias on pulse generator to 0, set PRF to 1 MHz square wave.
3. Connect diode and resistor in series to generator. Turn bias until 5 ma DC bias is reached (read on scope).
4. Turn amplitude knob to 105 ma peak.
5. Position APD in front of LED. Read rise and fall times on scope and record.



Rise and Fall Time.

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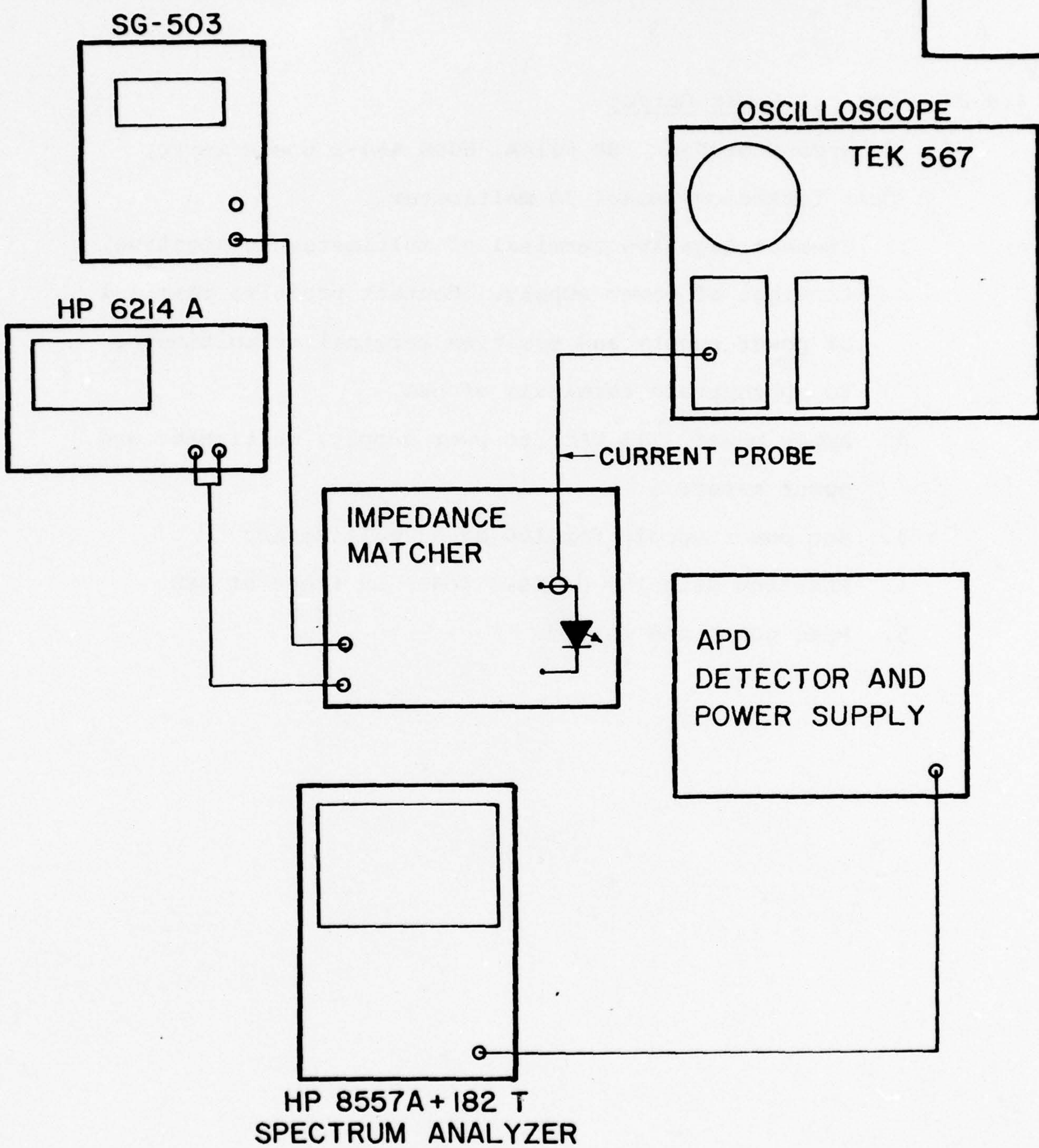
4.6.7 Bandwidth

Equipment: Tek S6 503, sinc wave generator, HP 182T display, HP 8557A spectrum analyzer, impedance matching box. Scope Tek 567 with 3576, 3T77 A plug-ins, HP power supply 6214A. APD detector and power supply, current probe.

1. Apply power to SG 503, HP 6214A, Tek 567, APD, and HP 8557A, 182T.
2. Mount diode in impedance matching box. Connect to 6214A and turn to 100 ma bias.
3. Connect SG 503 to impedance matching box. Set frequency to 40 MHz. Turn output to 100 ma peak to peak. Read on scope.
4. Connect APD to spectrum analyzer position APD in front of LED and termine 3 DB intensity points and record.
5. Turn frequency on SG 503 to 32 MHz. Determine 3 DB point and record. Turn to 44 MHz. Determine 3 DB point and record.



Bandwidth.

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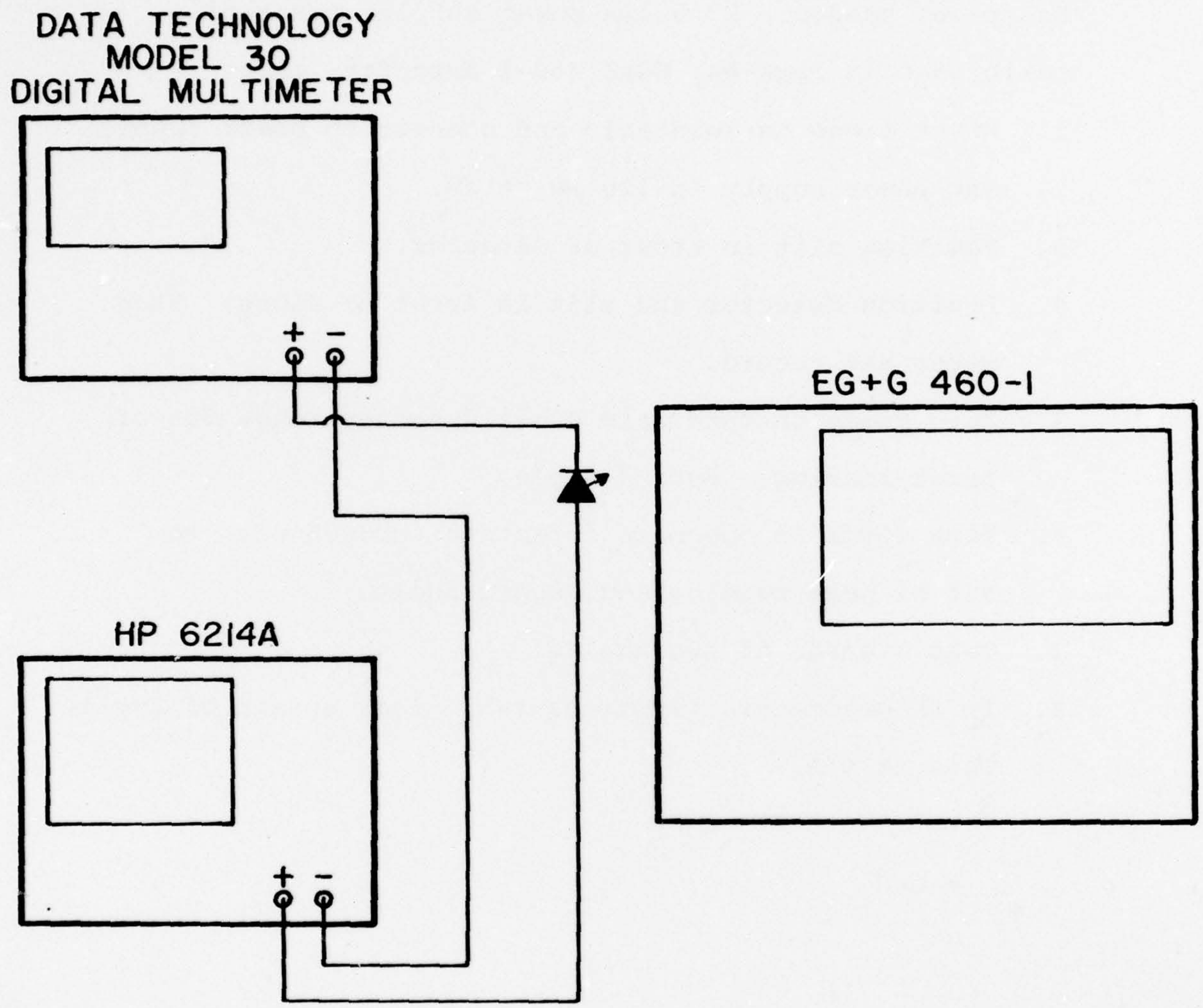
4.6.8 <u>Optical Power Output</u>

Equipment Needed: HP 6214A, EG&G 460-1 power meter, Data technology Model 30 multimeter.

1. Connect negative terminal of multimeter to negative terminal of power supply. Connect positive terminal of power supply and positive terminal of multimeter to appropriate terminals of LED.
2. Apply power (115 VAC) to pwer supply, multimeter and power meter.
3. Set power supply for 100 ma on multimeter.
4. Position detector of EG&G 460-1 in front of LED.
5. Read power and record.



Optical Power Output.

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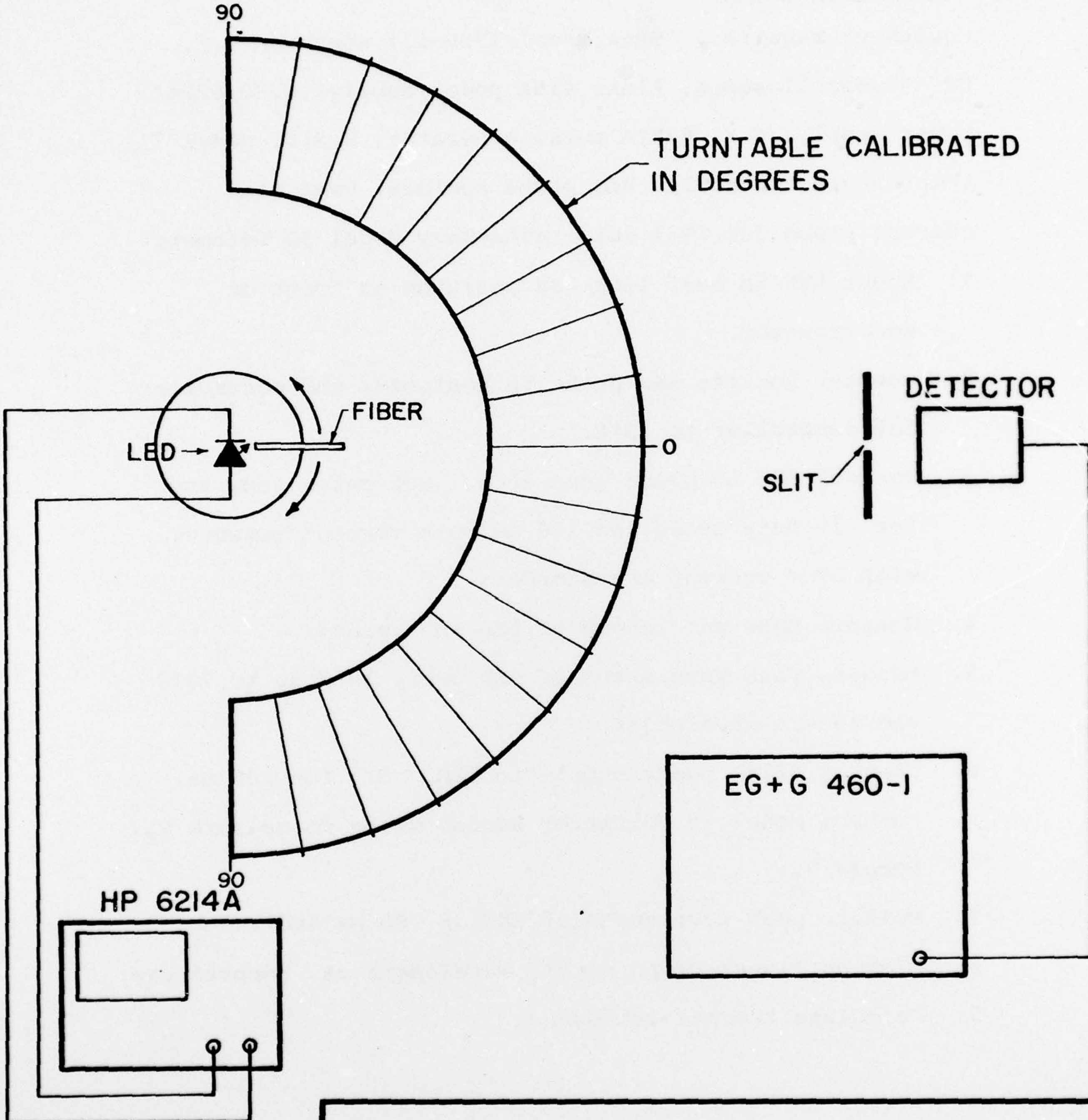
4.6.9 Numerical Aperture

Equipment needed: HP 6214A power supply, turntable calibrated in degrees, EG&G 460-1 detector, slit

1. Mount diode on turntable and connect to power supply.
2. Set power supply to 100 ma at 2V.
3. Position slit in front of detector.
4. Position detector and slit in front of fiber. Read meter and record.
5. Turn diode on turntable until detector reads 50% of first reading. Record angle.
6. Turn diode in opposite direction through peak to 50% of peak reading and record angle.
7. Take average of two angles.
8. In trigonometric functions table look up sin of angle. This is N.A.



Numerical Aperture.

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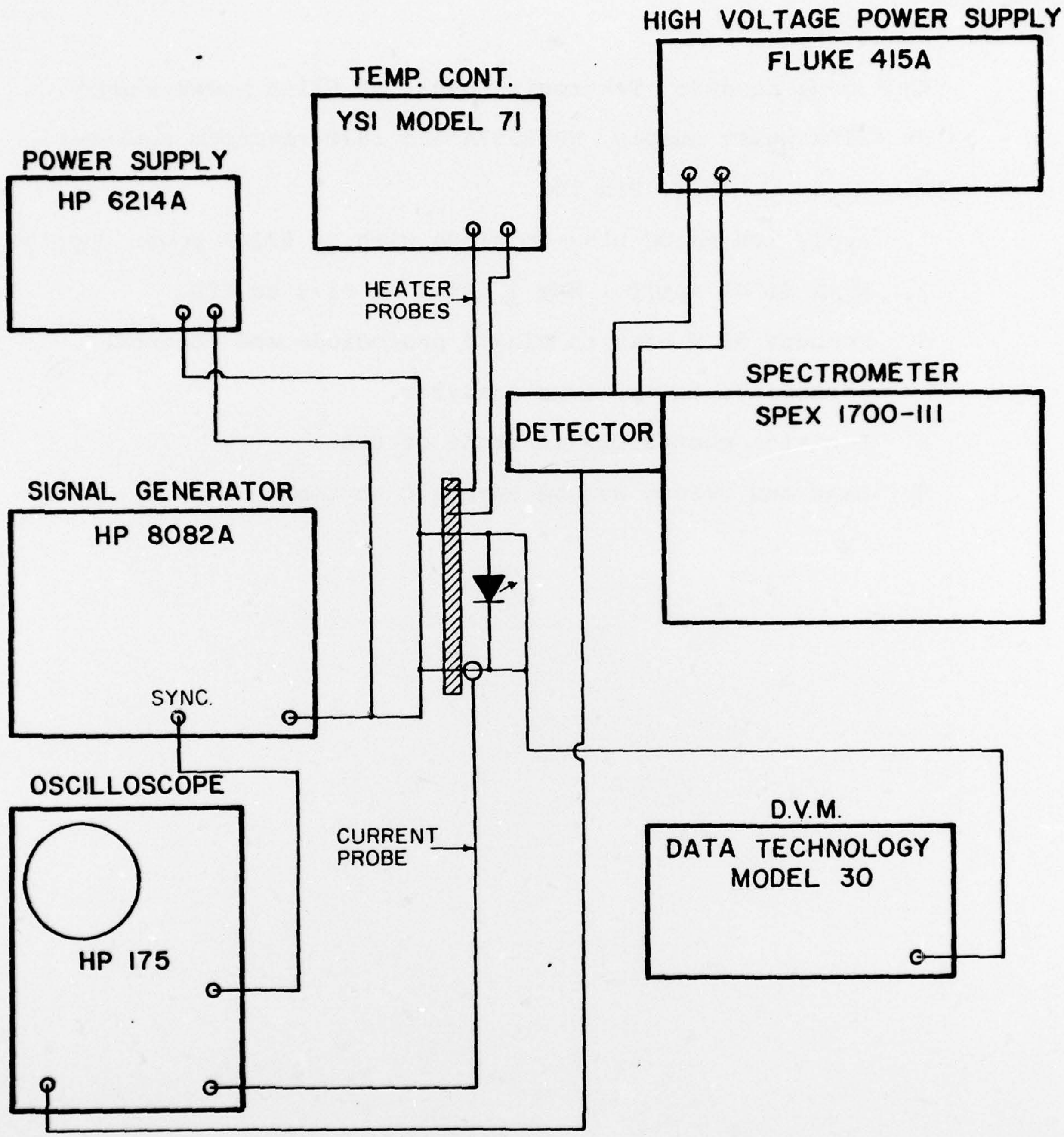
4.6.10 Thermal Impedance

Equipment required: Spex Model 1700-111 spectrometer, HP 175 oscilloscope, Fluke 415A power supply, H.P. 6214A power supply, H.P. 8082A pulse generator, U.S.I. MOdel 71 temperature controller and probe heaters, heat sink, current probe Tek CT-2 data technology Model 30 Voltmeter.

1. Mount LED in heat sink and position in front of spectrometer.
2. Connect heaters and probe to heat sink and controller. Set controller to 20°C.
3. Connect LED to pulse generator. Set pulse generator for .1% duty cycle and 100 ma peak current measured with CT-2 current transformer.
4. Measure peak wavelength of LED and record.
5. Measure peak wavelength of LED every 10°C up to 70°C and record wavelength.
6. Connect 6214A power supply to LED. Set for 100 ma, connect Model 30 Voltmeter across diode to measure V_f. Record V_f.
7. Measure peak wavelength of LED at 100 ma and record.
8. Plot on linear graph paper, wavelength vs. temperature.
9. Calculate thermal impedance.



Thermal Impedance.

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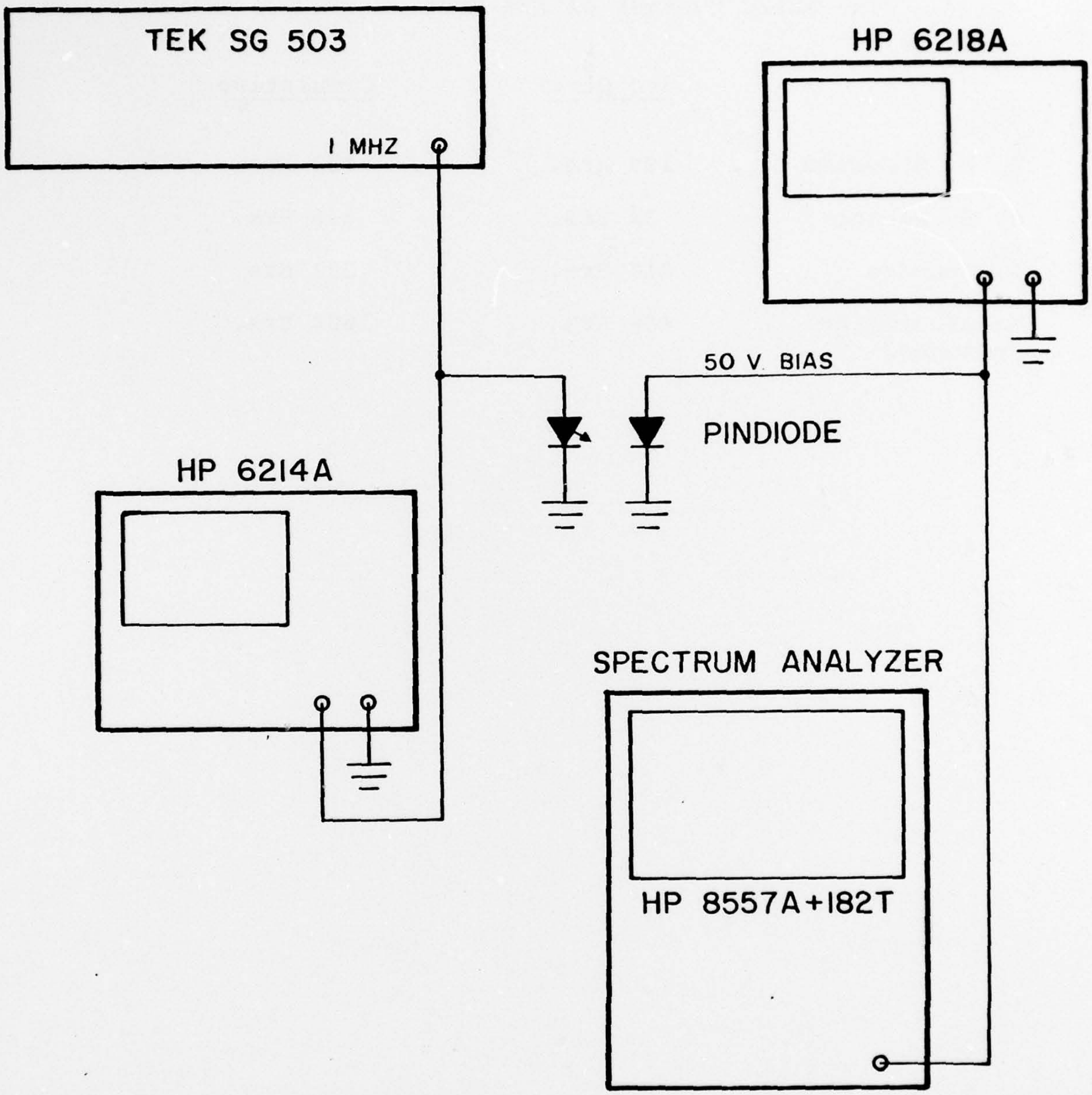
4.6.11 Linearity

Equipment needed: Tektronix S6503, HP 6214A power supply, HP 6218A power supply, HP 8557A and 182T spectrum analyzer, Pin diode L.L.D.T. Pin 10.

1. Apply 100 ma DC bias to diode with HP 6214A power supply.
2. With S6503 apply 1 MHz ± 50 ma AC bias to LED.
3. Connect 50 V bias to Pin-10 photodiode and connect photodiode to Spectrum analyzer.
4. Position photodiode in front of LED.
5. Read and record second harmonic content.



Linearity.

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APPENDIX B

Engineering Man-Hour Utilization for the Third Quarter of the Program.

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