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ELECTRICAL AND OPTICAL STUDY OF SEMICONDUCTOR LASER DIODES AND MATERIALS

By

Sacharia Albin, Principal Investigator

Final Report
For the period ended August 31, 1987

Prepared for the
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

Under
Master Contract Agreement NAS1-17993
Task Authorization No. 48
Robert V. Hess, Technical Monitor

September 1987

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Norfolk, Virginia 23508

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ELECTRICAL AND OPTICAL STUDY OF SEMICONDUCTOR LASER DIODES AND MATERIALS

By

Sacharia Albin*

SUMMARY

Diode laser array characterization was completed during the award period. The pertinent results of each experimental study are summarized below.

The 2-D array from McDonald Douglas consisted of 8 linear arrays of approximately 11 mm x 0.18 mm. Each array has between 7 and 8 diodes per mm. The threshold current for this 2-D array is around 15 amps. More details are given in the attached experimental report number one.

Next, the power output vs drive current (above threshold) of the array was measured. The measurement procedures and results are described in experimental report number two. A peak power of 50 W was obtained at a drive current of 26 amps.

The report of experiment number three describes in detail the experiment carried out to measure the far field pattern of the 2-D array. The far field has a double lobe pattern.

Results of this study were presented at the Virginia Academy of Sciences Meeting, May 1987.

*Associate Professor, Department of Electrical and Computer Engineering, Old Dominion University, Norfolk, VA 23508.

EXPERIMENT ONE

DIODE LASER ARRAY CHARACTERISTICS

PERFORMED BY

ADDISON INGE

JAMES NEW

1 /21/ 87

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INTRODUCTION

PURPOSE

The objective of experiment one is to measure the area of the diode laser array and approximate how many single laser diodes this area consist of.

PROBLEM

The diode laser array system is illustrated in figures one and two below. Figure one illustrates the current supply for the array system and figure two illustrates the diode array mount with the appropriate water coolant and nitrogen lines. The yellow tubing contains nitrogen gas, which prevents condensation from forming on the array. The two clear lines are the water coolant system lines. An infared camera is to be positioned in front of the array. This will allow for an approximation of the array's area using a metric ruler taped to the front of it. The number of individual light emmissions per millimeter per bar is to be approximated also.

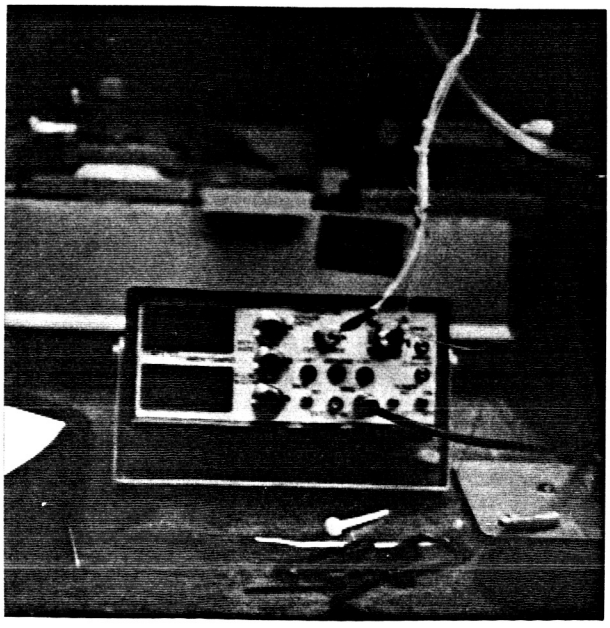

FIGURE 1

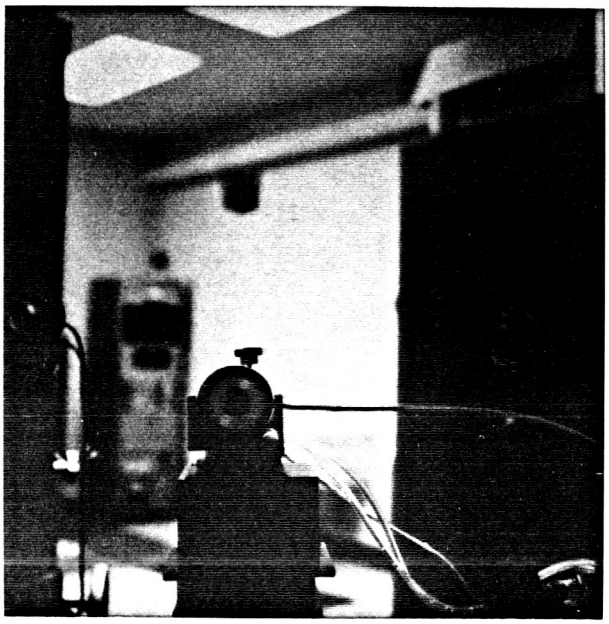

FIGURE 2

EXPERIMENTAL RESULTS

STEP 1: The camera was positioned in front of the diode laser array and positioned so as to see the array on the camera monitor.

STEP 2: A ruler was taped to the front of the array and positioned at a reference point so the length and height could be measured. The measurements were read from the camera monitor and was found to be 11mm by 0.18mm.

STEP 3: Rough calculations of the number of diodes per mm were made at a current not exceeding 2 Amps. A strong background white light source was directed on to the array in order to see the individual sources of laser light generated by each of the 8 one dimensional arrays which make up the array. The number of diode light emissions per mm was estimated between 7 and 8. The light emissions visualized at 2 Amps were essentially in the LED characteristic range of the diode laser. The threshold current for this particular array is approximately 15 Amps. Any measurements taken at currents below this threshold current will be LED emissions. The measurements taken are illustrated in figure 1 below.

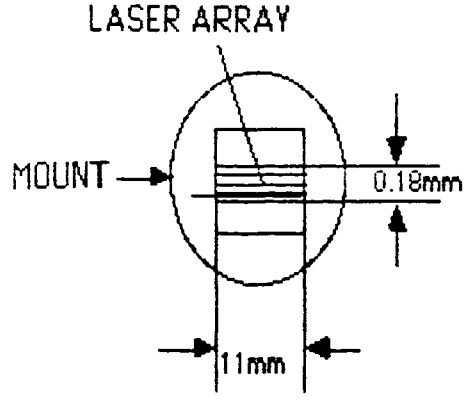

FIGURE ONE

LIST OF EQUIPMENT

1. McDonald Douglas Semiconductor Diode Array
    a. Array
    b. Array mount
    c. Power supply

2. RCA TV Camera and monitor
    Model 2000
    12.5 - 75 mm zoom lens

3. Coolant system

4. Nitrogen gas system

CONCLUSION

It was observed that approximately 7 to 8 diodes per mm per bar existed. Although these light emmissions appeared to be single laser diodes, in reality each single emmission may represent an indeterminate number of smaller emmissions grouped to appear as one. Since no information was provided with this array, it is not possible to determine the actual number of single diode lasers per bar with this information.

The area of the array was measured to a close approximation of the area suggested by the array manufacturer. The area was approximated to be 0.2 square centimeters.

EXPERIMENT 2

DIODE LASER ARRAY CHARACTERISTICS

PERFORMED BY

ADDISON INGE

JAMES NEW

1 / 28 / 87

INTRODUCTION

PURPOSE

The objective of this experiment is to obtain the peak power output of the semiconductor diode laser array.

PROBLEM

The diode array consist of two parts; the array mount and a current supply. The diode is configured in the mount as illustrated in figure 1.

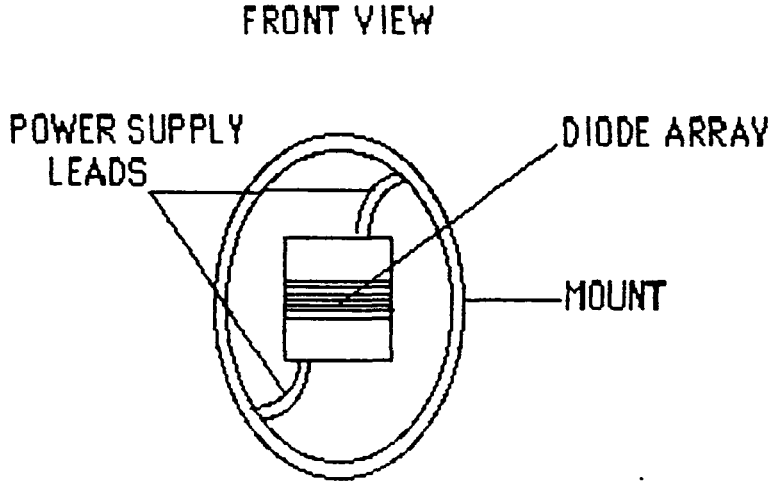

FIGURE ONE

The dimensions of the array was found to be approximately 11mm by 0.18mm. The array mount also holds the coolant lines used to control the operating temperature of the array. The array consist of 8 one dimensional arrays stacked on top

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of each other.

The current supply, supplied with the array, features a digital display for the current being suuplied to the array and the temperature in degrees celsius. The pulse width and repetition rate of the current supply can be controlled as illustrated in figure 2.

The coolant system consist of a refrigeration unit with an electric pump. The controoller is a RTE-4 circulator which allows for room temperature or refrigerated water flow. Nitrogen gas is also supplied to the array as illustrated in figure 3. The yellow tubing shown in the picture is the nitrogen and the 2 clear lines are the water coolant lines.

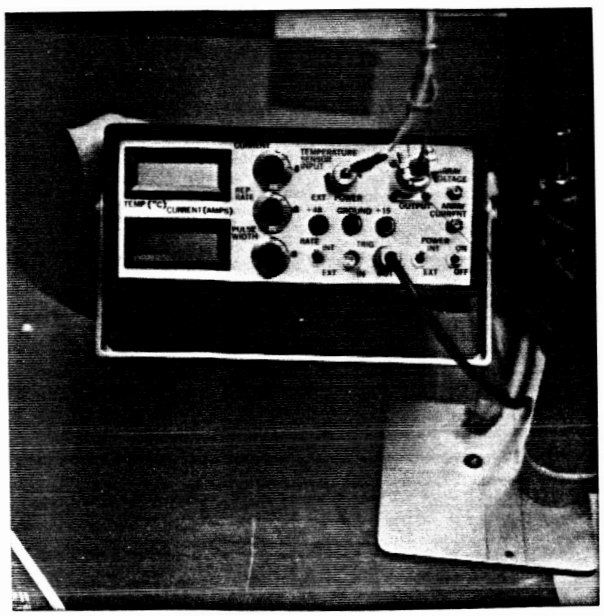


FIGURE 2

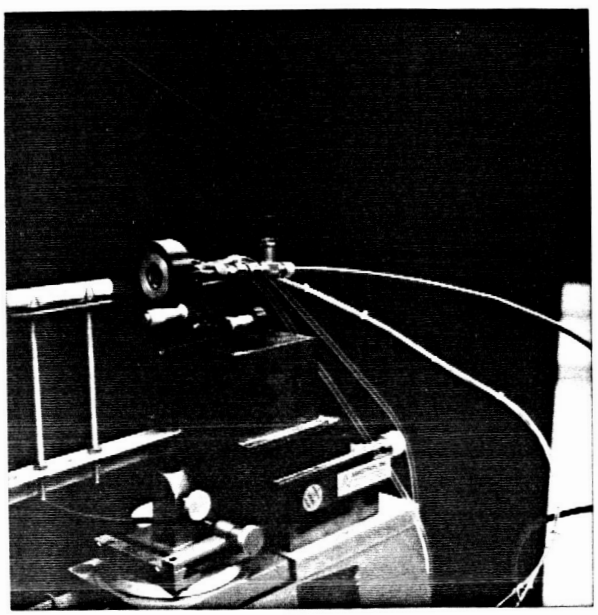


FIGURE 3

The only characteristics provided with the array is its maximum output power and its area which is 150 Watts and 0.2 sq. cm, respectively. A method for obtaining the peak output power is accomplished with a power energy detector and a photodiode detector. The average power is obtained with the power detector and the pulse width is determined with the photodiode. The circuit configuration of the photodiode detector is shown in figure 4.

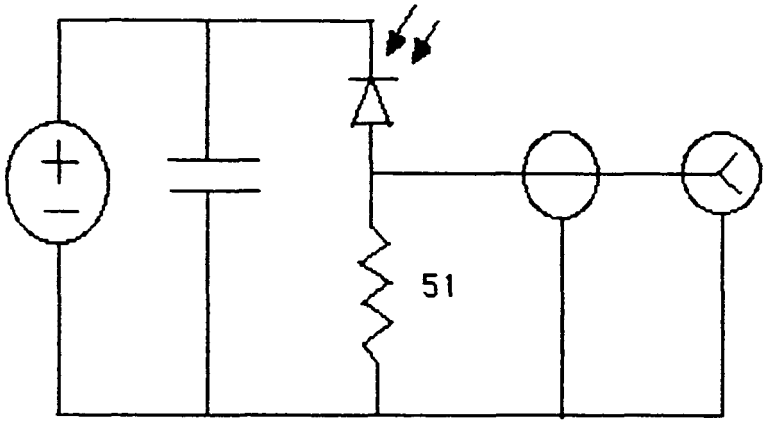


FIGURE 4

The average power is related to the peak power by the following relationship,

(1) $P(peak) = P(average)/ tN,$

where t is the pulse width and N is the number of pulse widths per second. N can be adjusted using the rep rate control of the current supply.

LIST OF EQUIPMENT

1. RCA TV Zoom lens camera and monitor

   Model 2000

   12.5 - 75mm lens

2. Scientech Power Energy Detector

   Model 360001

3. Textronix Oscilliscope

   Model 485

4. PIN Silicon Photodiode Detector

5. Water coolant system and Nitrogen bottle

6. McDonald Douglas Semiconductor Diode Laser

   Array System (includes power supply)

7. Scientech Power Energy Meter

   Model 362

EXPERIMENTAL RESULTS

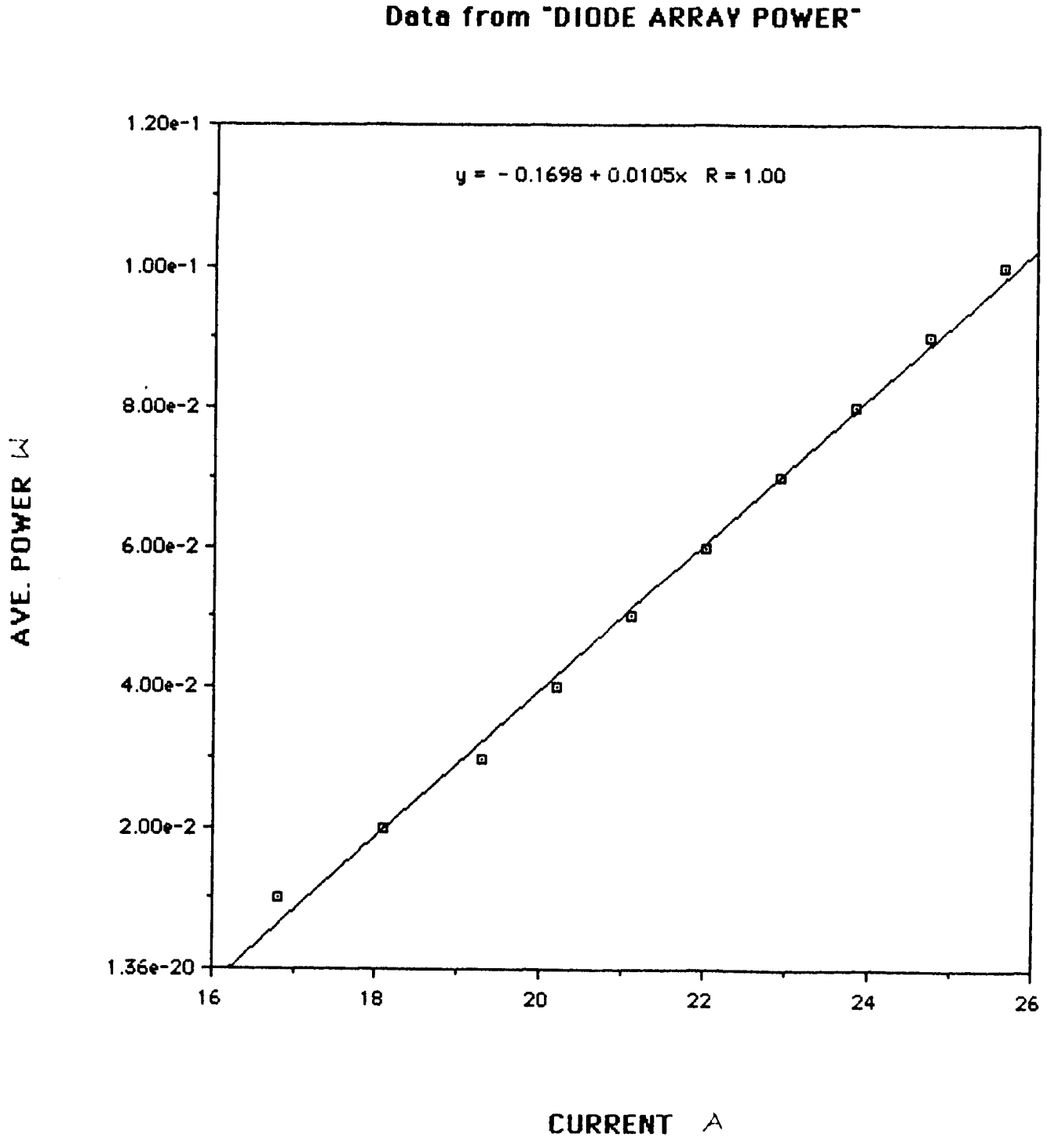
STEP 1: Turned on coolant system and obtained an operating temperature of 18 degrees celsius.

STEP 2: The power energy detector was configured in front of the diode array and the power meter was set on the 0.1 range setting.

STEP 3: The diode array current supply was set to zero and turned on. The current was slowly brought up to the threshold current of 15 Amps and measurements were then taken ranging the power from 0.01 to 0.1 Watts in .01 increments. At each of the values of power, the current was measured and tabulated.

STEP 4: Since the average power was measured using the method of step 3, it was then necessary to obtain the pulse width in order to calculate the peak power using equation 1. The rep rate was set to 10 reps per second. The PIN silicon detector was connected to the oscilliscope and the time delay was set for 50 microseconds per division. The pulse width was found to be approximately 200 microseconds regardless of the distance of the detector from the array, although the magnitude of the pulse did vary with distance.

STEP 5: From this information, the peak output power of the array could be calculated. The peak power was found, using equation 1, to be approximately 50 Watts at a current of 26 Amps.


Data from "DIODE ARRAY POWER"
y = - 0.1698 + 0.0105x R = 1.00
1.20e-1
1.00e-1
8.00e-2
6.00e-2
4.00e-2
2.00e-2
1.36e-20
AVE. POWER W
16
18
20
22
24
26
CURRENT A

CONCLUSION

Within this experiment, it was determined that the peak power of the diode array is 50 Watts at a current of 26.5 Amps. The average power was obtained with a power energy detector and was found to be 0.1 Watts at 26.5 Amps. The pulse width was found to be 200 microseconds by means of a photodiode detector and an oscilliscope. From the following relationship,

$$P(peak) = P(average)/(pulse\ width)(rep\ rate),$$

the peak power was calculated. The rep rate was set to 10 pulses per second. The temperature was maintained at 18 degrees celsius throughout the experiment.

EXPERIMENT THREE

DIODE LASER ARRAY CHARACTERISTICS

PERFORMED BY

ADDISON INGE

JAMES NEW

MACK HASEMIAN

3 / 2 / 87

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INTRODUCTION

PURPOSE

The objective of experiment 3 is to measure the field pattern of the diode laser array at various distances from the array.

PROBLEM

Measurements will be taken at various (3) positions from the array using a photodiode detector. The current supplied to the array will be approximately 24 Amps at 18 C. The vertical position of the photodiode will be varied 3 positions above and below the horizontal position corresponding to the center of the array. At each horizontal and vertical position, a full 180 angle (+90 to -90) will be swept out and the intensity of the diode array will be plotted using an X-Y recorder. Figure one illustrates the experimental equipment outlined above. Figure two shows the X-Y recorder used for these measurements.

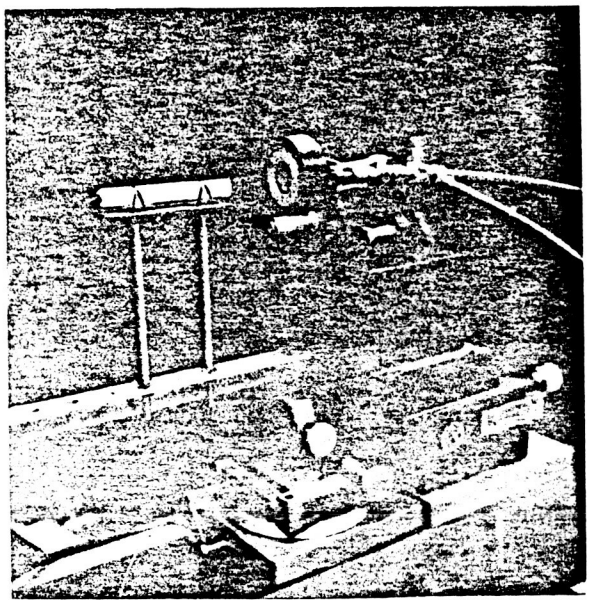

FIGURE ONE

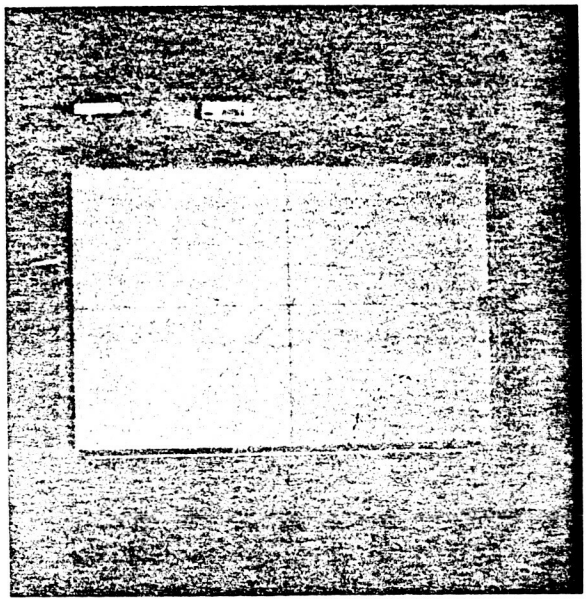

FIGURE TWO

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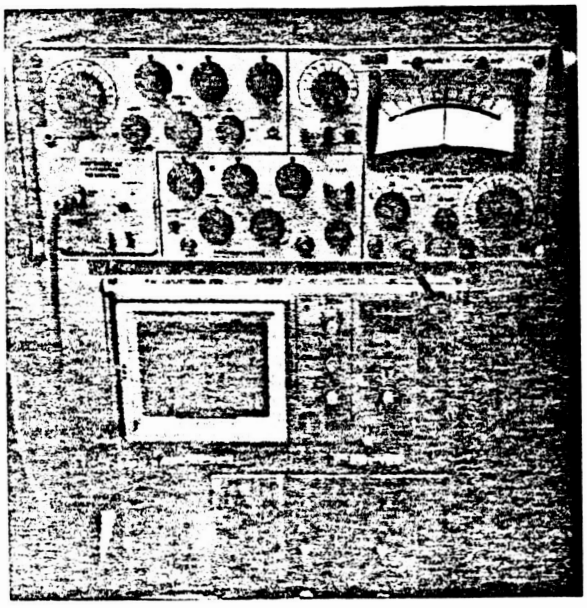


FIGURE 3

FIGURE FOUR

The detector is mounted on two short lengths of threaded rod attached to an aluminum arm. The aluminum arm is connected to pivot point centered underneath the array which controls a precision potentiometer. The potentiometer is connected to the X-Y recorder by means of a dc voltage supply. As the arm is swept from one side to the next , it will show up as movement in the X direction on the recorder.

The photodiode detector is first channeled through an attenuator and then routed to a PAR MODEL 117 differential preamplifier, illustrated in figure three above. The signal is then taken from a PAR MODEL 124 lock-in amplifier and connected to the X-Y recorder. From this configuration, shown in figure four, the intensity of the array will show up as changes in the Y direction.

The array will be operated at 24 Amps current at 18 C.

LIST OF EQUIPMENT

1. PAR MODEL 117 DIFFERENTIAL AMPLIFIER
   (connected to detector channel A- 100M , 20pf)

   SIGNAL CHANNEL
   Sensitivity - 5
   Mode - Band Pass
   Frequency - 1.55(10) Hz
   Q - 2(10%ENBW)

   TIME CONSTANT - 100ms

2. PAR MODEL 124 LOCK-IN AMPLIFIER (2Hz to 210kHz)

   REFERENCE CHANNEL
   Frequency - 1.00(10) Hz
   Level - 0 volts rms
   Phase - 180

   CALIBRATOR - 50 nVolts

   PSD - High dynamic range

   FUNCTION - OUT

3. HEWLETT-PACKARD MODEL 7044A X-Y RECORDER

   Y-direction (input from PAR MODEL 124 LOCK-IN AMPLIFIER)
   Polarity - +up
   Range - 1mV/in.

   X-direction (input from precision potentiometer)
   Polarity - +right
   Range - 0.5mV/in.

4. DIODE LASER ARRAY SYSTEM

5. HEWLETT PACKARD ATTENUATOR/11dB MODEL 8494A

6. HARRISON LABORATORIES MODEL 865B POWER SUPPLY (supplies dc voltage for the precision potentiometer, $\simeq$ 3 Volts dc)

7. BECKMAN MODEL TECH360 DIGITAL MULTIMETER (used to monitor the voltage which is related to the angle of the precision potentiometer)

8. LIQUID WATER COOLANT SYSTEM

9. NITROGEN GAS (demoisturizer)

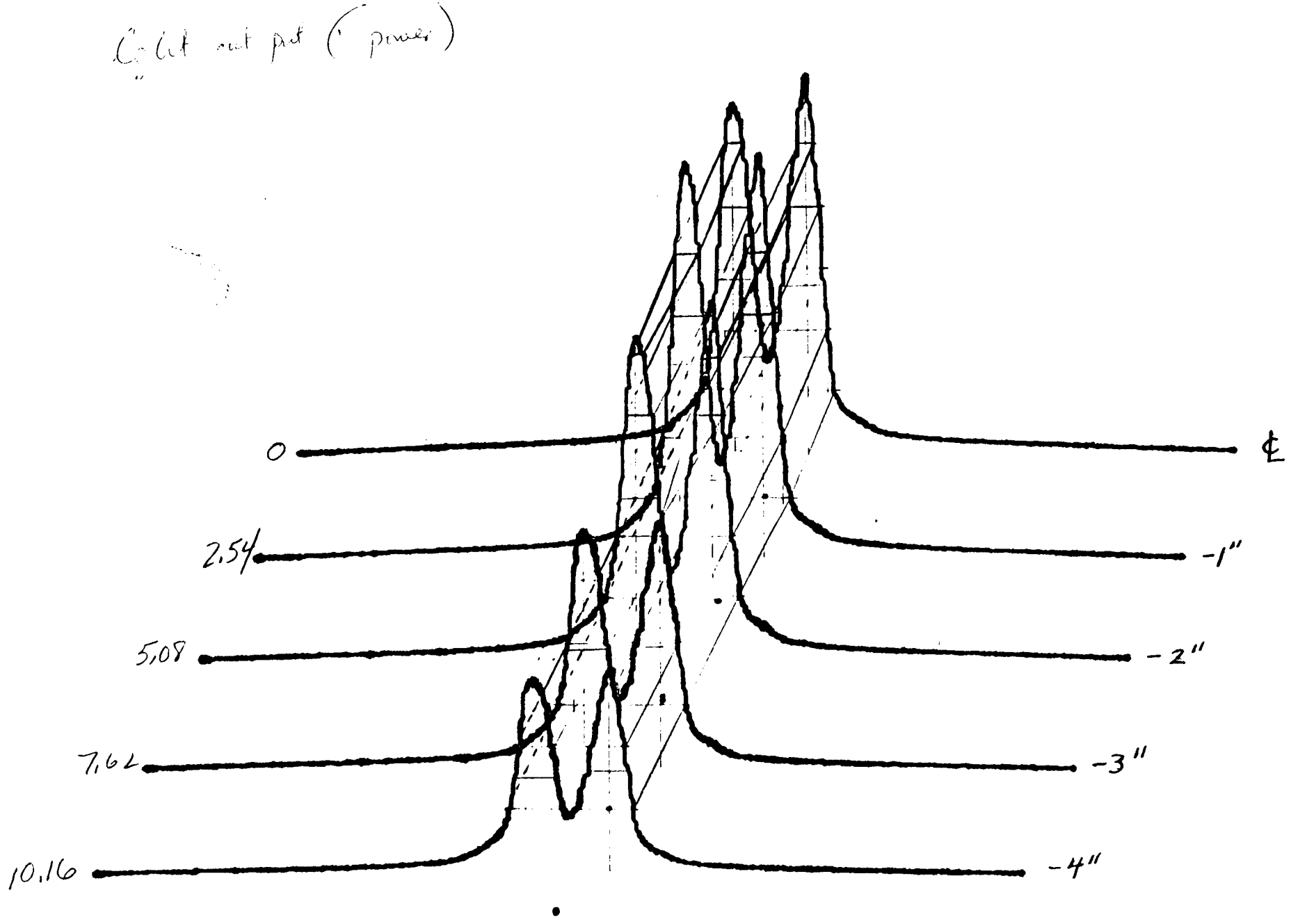
EXPERIMENTAL RESULTS

The photodiode detector was positioned approximately 30.48 cm from the array. Measurements were taken at the center of the array from -90 degrees to +90 degrees. This line is labeled ℄ on graph one of the appendix. Four more measurements were taken at the same distance from the array but lower than the center line by inch increments.

The maximum heights of the graph were then plotted with respect to vertical displacement. Graph two illustrates the left side maximum values with respect to vertical position. Graph three shows the best fit fourth order polynomial function which approximates the given data. Graph four demonstrates the right side maximum values and graph five the best fit polynomial equation.

Also derived from graph one is a contour map of the gain profile with respect to vertical displacement. The different levels are denoted in centimeters as shown on the left side of graph one. The lines cutting the gain profile correspond to the layers shown on graph six. The solid colored lines represent an approximation of the layer to the actual experimental values and the dashed, colored lines correspond to the draftsmans interpretation of the profile.

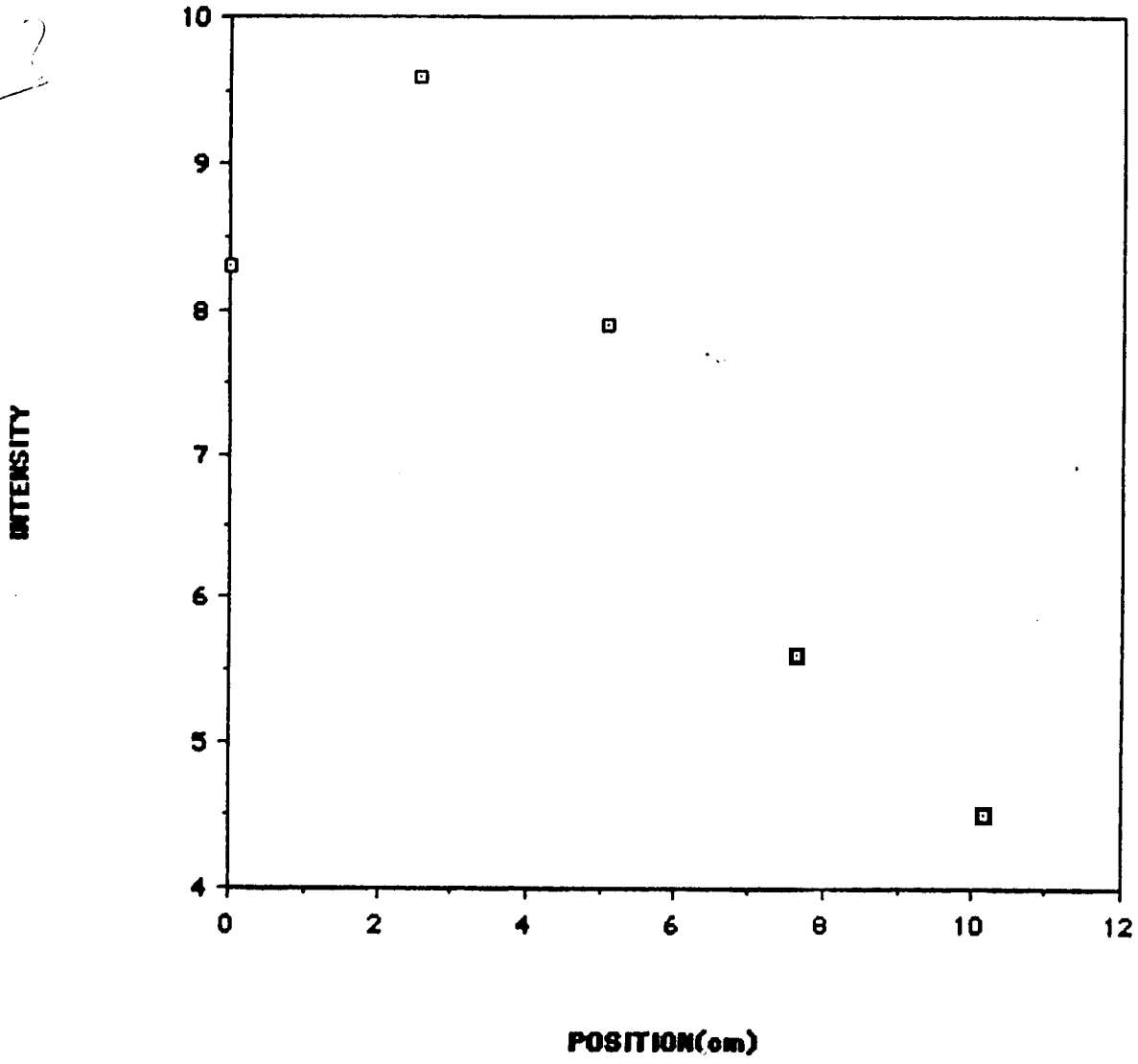
APPENDIX



GRAPH 1

SCAN ± 45°

DIODE ARRAY : INTENSITY vs. POSITION (left)

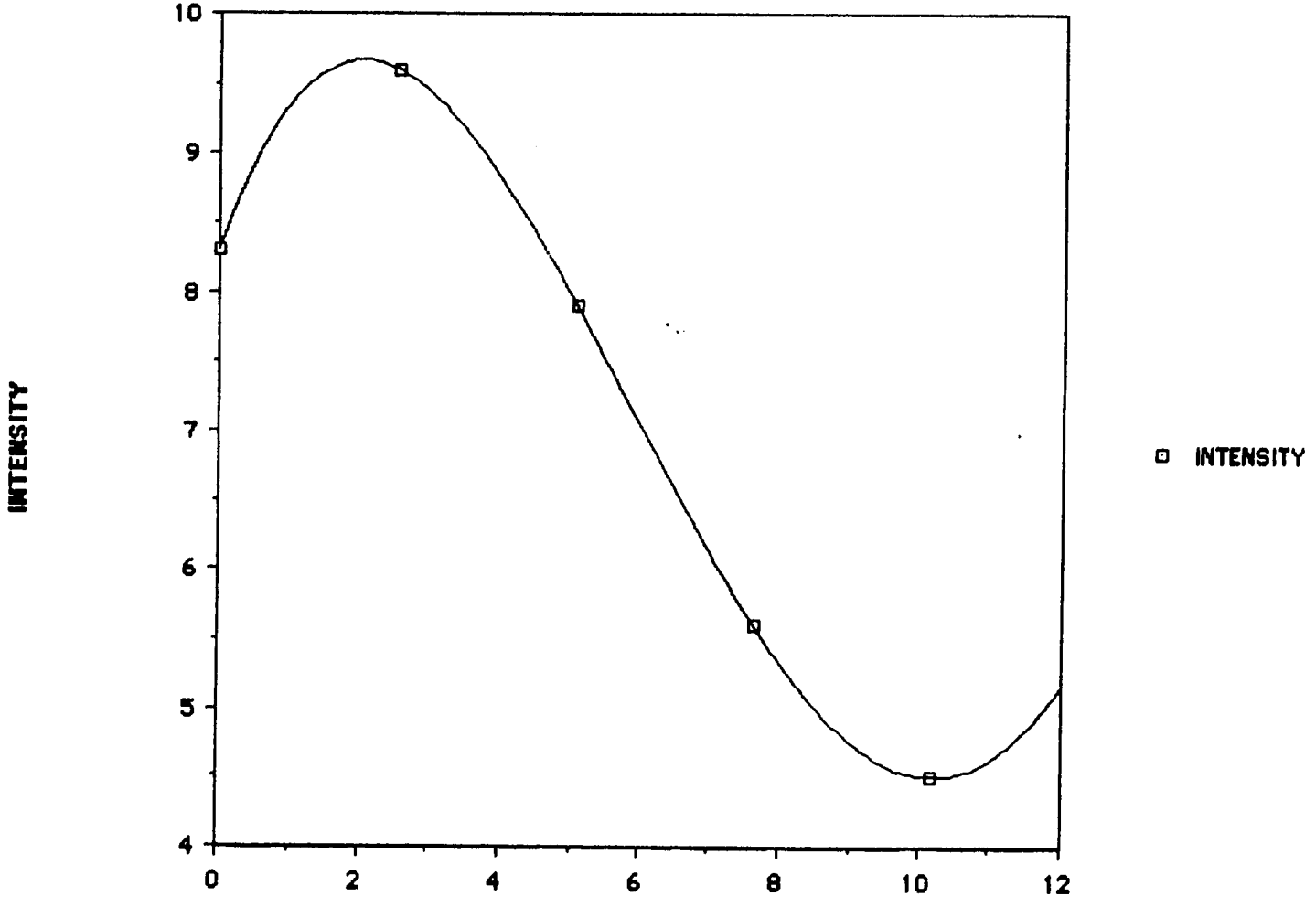


GRAPH 2

DIODE ARRAY : INTENSITY vs. POSITION

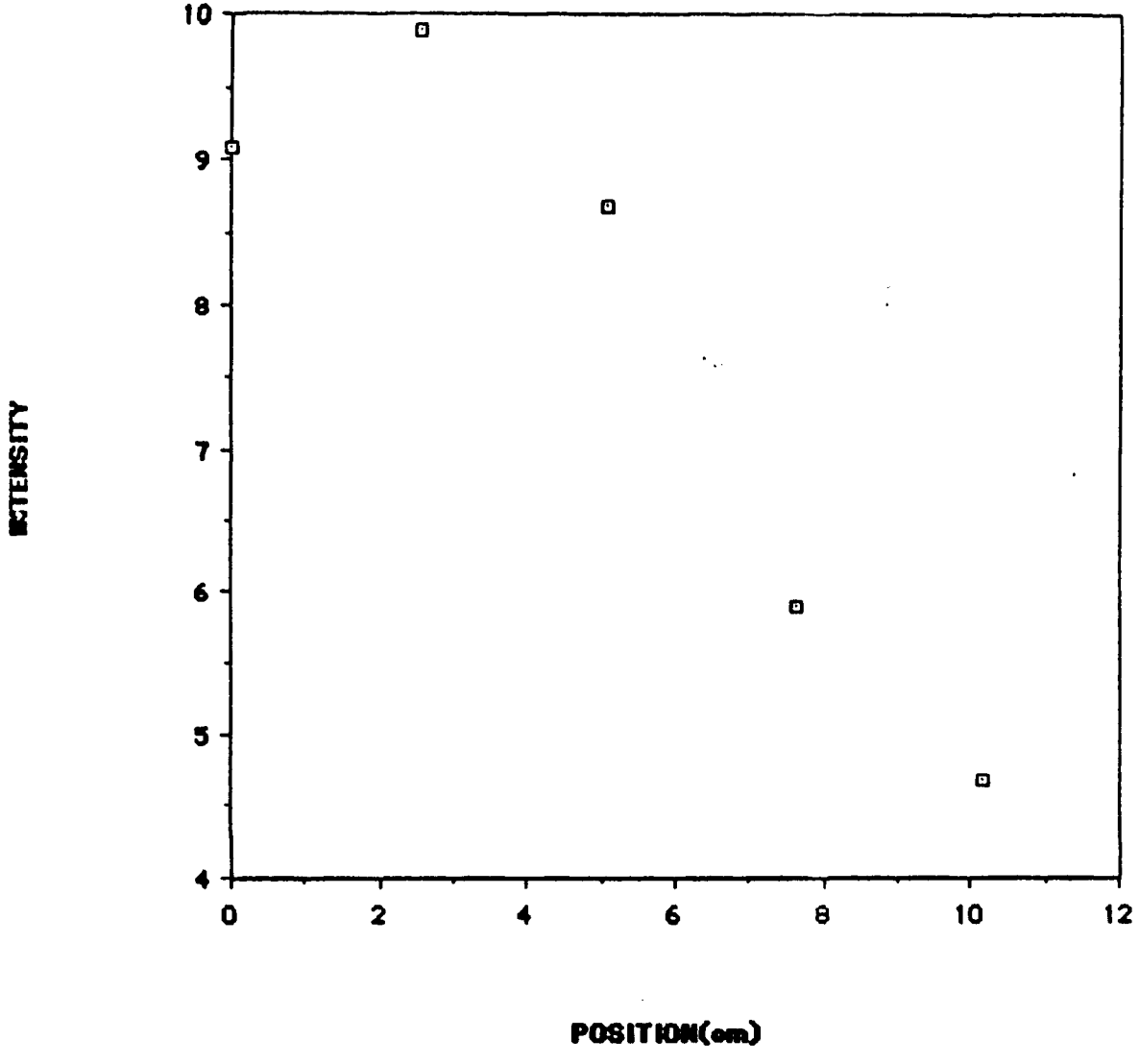
left

y = 8.3 + 1.4764x - 0.4611x^2 + 0.0336x^3 - 6.006e-4x^4 R = 1.00



GRAPH 3

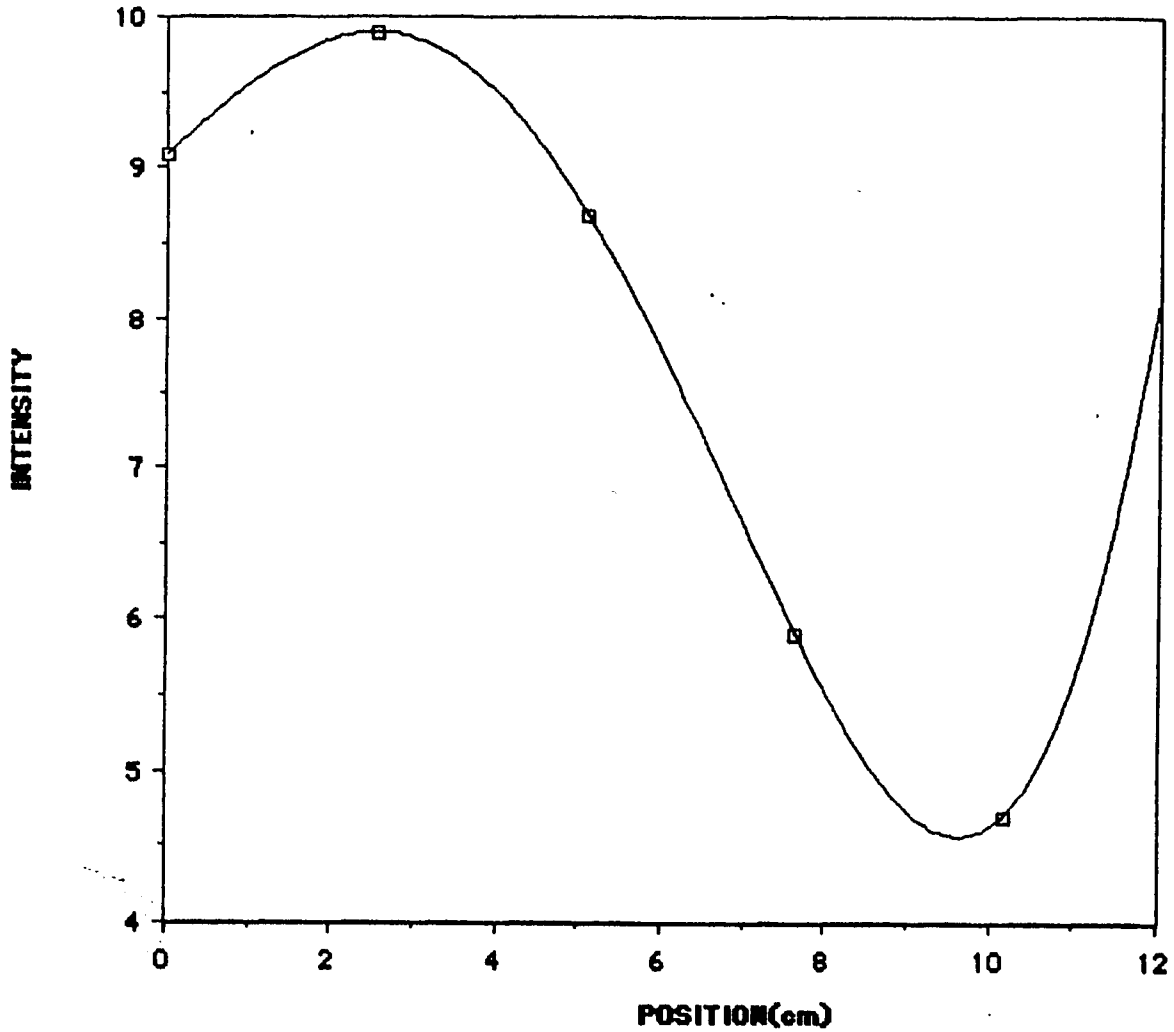
DIODE ARRAY : INTENSITY vs. POSITION (right)



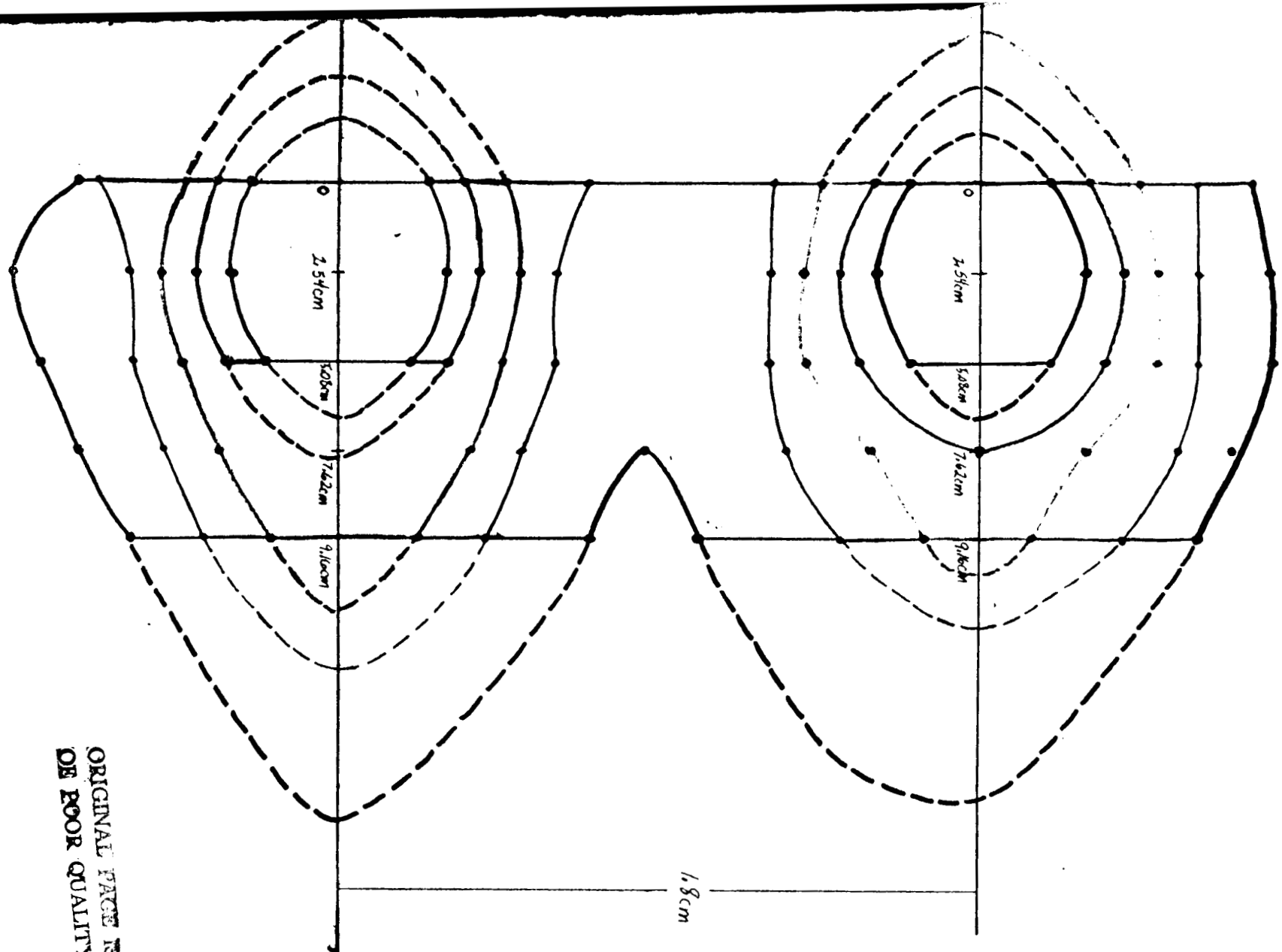
GRAPH 4

DIODE ARRAY : INTENSITY vs. POSITION Right

y = 9.1 + 0.4856x + 0.0129x^2 - 0.0386x^3 + 0.0028x^4 R = 1.00



GRAPH 5



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GRAPH 6

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MATERIAL | SCALE

TOLERANCE ON DIMENSIONS UNLESS SHOWN OTHERWISE
ANGULAR ±
X.X (1 DECIMAL PLACE ± .1)
X.X X (2 DECIMAL PLACES ± .02)
X.X X X (3 DECIMAL PLACES ± .005)

SURFACE FINISH IN MICROINCHES RMS UNLESS SHOWN OTHERWISE

EST. FIN. WEIGHT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
HAMPTON, VA. 23665

PROJECT TITLE

DRAWING TITLE

A