(2)

**Northeast Semiconductor, Inc.**

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August 31, 1992

Dr. Erhard Schimitschek, Scientific Officer
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REF: N00014-91-C-0222
Naval Ocean Systems Center
271 Catalina Boulevard
San Diego, CA 92152-5000

Re: Contractor : Northeast Semiconductor, Inc.
Address : 767 Warren Road, Ithaca, NY 14850
Req. No. : s405811srv02/17 APR
Contract No. : N00014-91-C-0222
Report Date : August 31, 1992
Report Title : 7th Monthly Technical Report
Period Covered : 08/01/92 through 08/31/92

Dear Dr. Schimitschek:

Northeast Semiconductor, Inc. encloses its Seventh Monthly Technical Report (Line Item #0002) pursuant to the provisions of contract Section B entitled, "Supplies or Services and Prices/Costs" for the period of August 1, 1992 through August 31, 1992.

# Innovative Techniques for the Production of Low Cost 2D Laser Diode Arrays

## 1.0 OBJECTIVE

The primary objective of this program is to develop a low cost, high yielding methodology for processing, packaging and characterization of MBE grown two dimensional high power laser diode arrays. Projected increases in overall yield of AlGaAs diode lasers would reduce manufacturing cost from the current $10 to $20 per peak watt to below $3 per peak watt. Emphasis will be placed on innovative packaging techniques that will utilize recent advances in diamond heat sinking technology.

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## 2.0 PROGRAM METHOD AND SCHEDULE

This program consists of four phases which will demonstrate reduced manufacturing cost and improved device performance of NSI's MBE laser diode arrays. The four phases listed below will result in milestones in processing, packaging, and testing along with delivery of the specified number of 5-bar laser arrays.

(i) Concept phase: Conceptual design and organization of this phase II program. NSI will utilize the current side cooled package to manufacture 5-bar laser diode arrays for base line evaluation. (Deliverables: 3 5-bar arrays.)

(ii) Backplane phase: Investigation of backplane cooling technologies that incorporate BeO, W/Cu and CVD diamond materials. This phase will also include the completion of room temperature photoluminescence development. (Deliverables: 5 5-bar arrays.)

(iii) Optimize Backplane phase: Investigate and optimize various backplane technologies. This will involve evaluating different packaging materials and processes pertaining to thick films, copper, direct bond copper to BeO, W/Cu and CVD Diamond. Feasibility and cost will be dominant factors. (Deliverables: 5 5-bar arrays.)

(iv) Liquid Cooled phase: The best proven backplane technology developed to date will be incorporated into a innovative liquid cooled assembly. Due to the numerous potential backplane schemes, this package type will be specifically designed to be compatible with the preferred backplane technology chosen. (Deliverables: 5 5-bar arrays.)

The following global issues not mentioned above will be investigated continuously throughout all four phases of this program:

(1) design and development of a mask set to increase processing and packaging yields,

(2) development and updating of MBE growth software,

(3) design and development of an in-house facet coating station,

(4) evaluation of different facet coating materials,

(5) development of automated tests,

(6) life test and burn-in development.

The master schedule for this program is shown in Table 1. Each phase will require wafer growth, processing, assembly and test. The schedule shows the estimated number of sample fabrications and tests, as well as the time of hardware deliverables and reports.

## 3.0 PROGRESS THIS PERIOD

### 3.1 Wafer Growths

Laser wafers grown at NSI's new MBE facility have exhibited lower photoluminescence (PL) intensities in comparison with past experience. Presently, no strong correlation exist between device performance and PL intensities. However, due to poor laser performance of processed material from the new facility, growth experiments have been initiated to improve the cladding layers and cladding/quantum well interfaces. Hall measurements are also being done on wide-spacer MODFET's and doped $Al_{0.45}Ga_{0.55}As$ to calibrate doping levels and verify cladding layer quality. MBE machine characterization will continue into September until growth parameters are better understood for producing high performance MBE laser material.

### 3.2 Processing

During this past month, NSI has installed a quality assurance procedure pertaining to visual inspection of the facet coatings on the laser diode bars. Test results indicates that facet coating defects contribute to poor device reliability. Initial categorizing of defects were done, and a facet coating inspection check sheet was generated as shown in figure #1 . Data from this list is then entered into a spread sheet for future yield and trend analysis.

Due to more stringent dimensional requirements associated with advances in packaging, variations in laser diode bar thickness from batch to batch had to be minimized. Figure #2 shows the measured bar thickness of various processed batches over the past few years at NSI. The range from ~60µm to ~110µm is unacceptable. Since identifying the large variation in thicknesses, additional care and inspection steps are taken during the lapping and polishing of the laser wafers. A target bar thickness of 95µm ±5µm has been set. Two wafers were processed since, resulting in thicknesses of 94µm and 97µm.

### 3.3 Testing

Primary efforts this past period involved testing of submounts for the third 5-bar laser diode array to complete the first set of deliverables. First, low current characterization of the individual submounts is performed. This was necessary since poor device performance, for the selected material, was associated with the creation of current leakage paths. The submount was then tested for optical output power, voltage, and wavelength at 2% duty cycle (200µsec/100Hz). On a pass/fail criteria, the submount was either archived or advanced to a partial burn-in test. The partial burn-in at the submount level consisted of operating the device at 40 watts output power at 2% duty cycle for 5 X $10^5$ pulses. This burn-in test sorts for infant mortalities and involves low current characterization and optical inspection after the 5 X $10^5$ pulses. Upon passing the above tests, the submounts were stacked into the 5-bar assembly. The stacked 5-bar laser diode array is then tested at 2% duty cycle. The results of ONR 5-bar array #Y11 is shown in figure #3. The 5-bar is then burned-in for an additional 5 X $10^5$ pulses at 2% duty cycle resulting in a total burn-in duration of 1 X $10^6$ pulses.

### 3.4 Assembly and Packaging

Emphasis this past month was placed on developments towards a backplane cooled array package. CVD diamond was chosen as the submount material for initial evaluation of different package geometries. The decision to utilize diamond as the submount material was prompted by several factors. The cost of CVD diamond has significantly decreased over the past few years. The reduction in cost coupled with the increase thermal conductivity of the diamond warranted investigation. Metalization of the diamond could be such that the submounts provide electrical isolation from the backplane. This advantage allows package configurations with solid and/or indexed backplanes. The diamond pieces received, to date, are continuously metalized facilitating the need for an indexed backplane. Two different types of metalized BeO backplanes have arrived. One has Ti/Pt/Au metalization an the other utilized direct bond copper. Advantages of direct bond copper to BeO are seen in the superior adhesion and low thermal resistance at the interface. Isolation grooves have been saw cut into the backplanes resulting in 250µm metal stripes on 375µm centers. Other options, namely thick film printing of the indexed backplanes are being investigated to eliminate the saw cut step and improve the accuracy. Thick film printing of the solder onto the isolated metal stripes of the backplane is also being explored.

Initial experimentation proved that piece part accuracy (including the laser diode bar) is essential for fixturing and proper registration of the components. The individual diamond submounts received exhibited poor edge quality and piece to piece dimensional consistency. Diamond vendors are currently working to improve there dimensional tolerances. Attempts in early September will utilize the substandard diamond submounts along with W/Cu pieces received stacked onto the indexed backplanes.

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Construction of the third 5-bar side cooled array was completed this past month. Individual submounts were fabricated and extensively tested to produce a reliable base line product for comparison to future backplane cooled models.

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|---|---|
| A-1 | |

## 4.0 PLANS FOR SEPTEMBER

NSI will continue characterization of the MBE machine to establish optimal growth condition "windows" for production of high quality laser material. Characterization of facet coating anomalies will be ongoing with analysis of new runs to reduce and/or eliminate defects.

Major efforts will be focused on developments of a backplane cooled array package. Emphasis will be placed on ease of assembly, cost, and evaluation of different submount materials and processes.

Very truly yours,

Joseph A. Smart,
Principal Co-Investigator
Northeast Semiconductor, Inc.

:nd
Encl: 1 Copy of 7th Monthly Technical Report

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DEPARTMENT : LASER PRODUCT LINE
PROJECT(S) : ONR PHASE II
N00014-91-C-0222

KEY
○ : Start Task
◇ : Milestone
△ : Completion Date 1
▽ : Completion Date 2

DATE : NOVEMBER 20, 1991
PREPARED BY : GEOFFREY T. BURNHAM
APPROVED BY :

| PAGE 1 of 2 MILESTONES | 1991 | | | | | 1992 | | | | | | | | | | | | 1993 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A |
| HIGH YIELD EPITAXIAL GROWTH | | | | | | | | | | | | | | | | | | | | | | | | | |
| SYSTEM QUALIFICATION | ○ | | | | △ | | | | | | | | | | | | | | | | | | | | |
| WAFER STARTS | | | | | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | |
| REVIEW INCOMING INSPECTION | ○ | | | | | △ | | | | | | | | | | | | | | | | | | | |
| UPDATE GROWTH SOFTWARE | ○ | | | | | | | | | | | | | | | | | | | | | | | | |
| WAFER PROCESSING | | | | | | | | | | | | | | | | | | | | | | | | | |
| PROCESSING STARTS | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | |
| DEVELOP ROOM TEMP PL TEST | ○ | | | | | △ | | | | | | | ▽ | | | | | | | | | | | | |
| DEVELOP FACET COATING | ○ | | | | | | | | | | | | | | | | | | | | | | | | |
| PACKAGING | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-BAR SUBMOUNTS | | | | 15 | 30 | 30 | 10 | 10 | 10 | 10 | 30 | 30 | 10 | 10 | 10 | 10 | 30 | 30 | 10 | 10 | 10 | 10 | 30 | 30 | |
| 5-BAR ARRAYS | | | | | | | | | | | | | | | | | | | | | | | | | |
| CURRENT | | | | | | | | 6 | | | | | | | | | | | | | | | | | |
| Cu BACKPLANE | | | | | | | | | | | | | 10 | | | | | | | | | | | | |
| CVD DIAMOND | | | | | | | | | | | | | | | | | | | 10 | | | | | | |
| EGW COOLED | | | | | | | | | | | | | | | | | | | | | | | | | 10 |
| TESTING | | | | | | | | | | | | | | | | | | | | | | | | | |
| DEVELOP AUTOMATED TESTS | ○ | | | | | | | | | | | | | | | | | | | | | | | | |
| LIFE TESTS/BURN-IN | ○ | | | | | | | | | | | | | | | | | | | | | | | | |

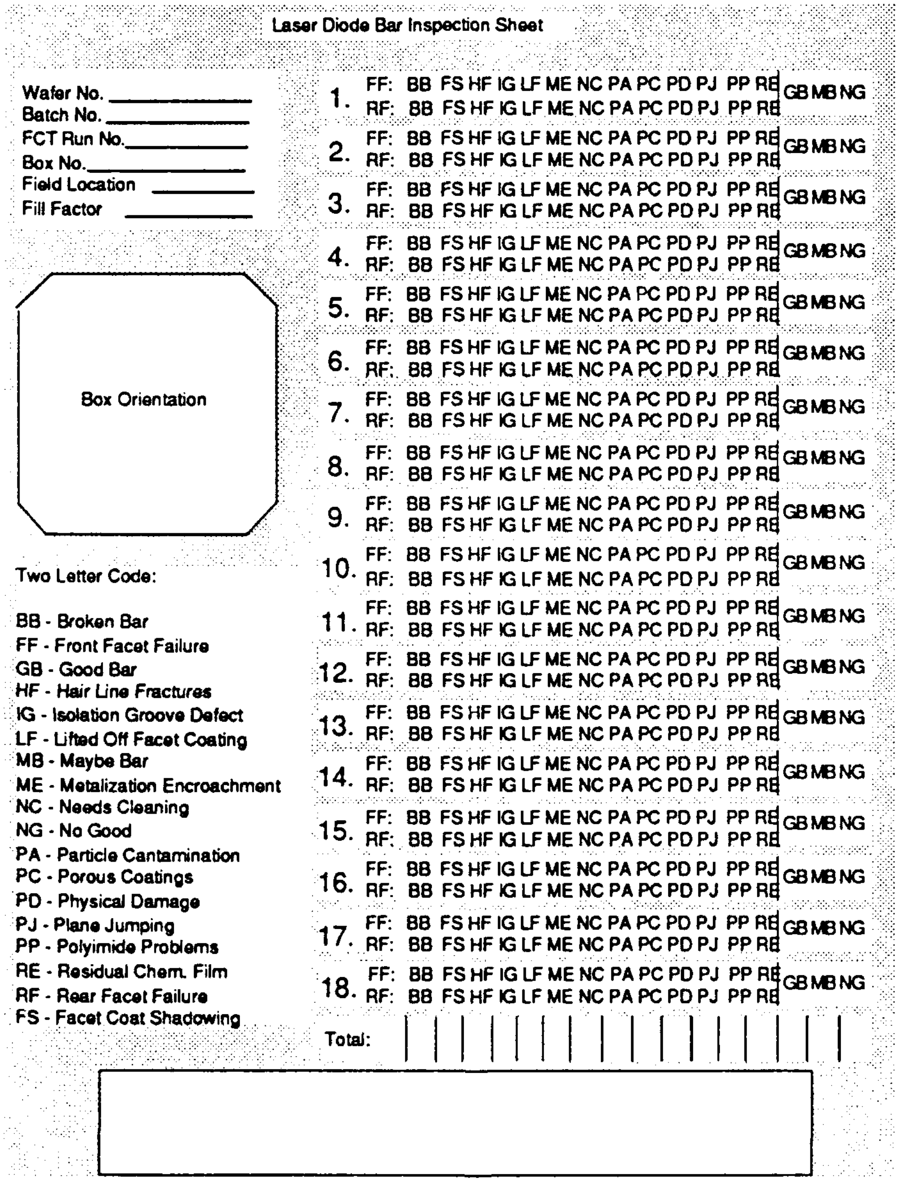
TABLE 1. MASTER SCHEDULE FOR SBIR PHASE II
CONTRACT NO. N00014-91-C-0222

DEPARTMENT : LASER PRODUCT LINE
PROJECT(S) : ONR PHASE II
N00014-91-C-0222

KEY
○ : Start Task
◇ : Milestone
△ : Completion Date 1
▽ : Completion Date 2

DATE : NOVEMBER 20, 1991
PREPARED BY : GEOFFREY T. BURNHAM
APPROVED BY :

| PAGE 2 of 2<br>MILESTONES<br>(CONTINUED) | 1991 | | | | | 1992 | | | | | | | | | | | | 1993 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A |
| TESTING (CONTINUED) | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5-BAR ARRAYS | | | | | | | | ○ | | | | | | | | | | | | | | | | | △ |
| DELIVERABLES | | | | | | | | | | | | | | | | | | | | | | | | | |
| REPORTS | | | | | | | | | | | | | | | | | | | | | | | | | |
| MONTHLY | | | | △ | △ | | △ | △ | | △ | △ | | △ | △ | | △ | △ | | △ | △ | | △ | △ | | |
| QUARTERLY | | | | | | △ | | | △ | | | △ | | | △ | | | △ | | | △ | | | △ | |
| FINAL | | | | | | | | | | | | | | | | | | | | | | | | | △ |
| 5-BAR ARRAYS | | | | | | | | | | | | | | | | | | | | | | | | | |
| CURRENT | | | | | | | | 3 | | | | | | | | | | | | | | | | | |
| Cu BACKPLANE | | | | | | | | | | | | | 5 | | | | | | | | | | | | |
| CVD DIAMOND | | | | | | | | | | | | | | | | | | | 5 | | | | | | |
| EGW COOLED | | | | | | | | | | | | | | | | | | | | | | | | | 5 |



Laser Diode Bar Inspection Sheet

Wafer No. ____________
Batch No. ____________
FCT Run No. ____________
Box No. ____________
Field Location ____________
Fill Factor ____________

Box Orientation

Two Letter Code:

BB - Broken Bar
FF - Front Facet Failure
GB - Good Bar
HF - Hair Line Fractures
IG - Isolation Groove Defect
LF - Lifted Off Facet Coating
MB - Maybe Bar
ME - Metalization Encroachment
NC - Needs Cleaning
NG - No Good
PA - Particle Cantamination
PC - Porous Coatings
PD - Physical Damage
PJ - Plane Jumping
PP - Polyimide Problems
RE - Residual Chem. Film
RF - Rear Facet Failure
FS - Facet Coat Shadowing

| | | | |
|---|---|---|---|
| 1. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| 2. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| 3. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| 4. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| 5. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| 6. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| 7. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| 8. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| 9. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| 10. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| 11. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
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| 12. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
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| 14. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
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| 15. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
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| 17. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
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| 18. | FF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | GB MB NG |
| | RF: | BB FS HF IG LF ME NC PA PC PD PJ PP RE | |
| Total: | | | |

FIGURE #1 LASER DIODE BAR INSPECTION SHEET
CONTRACT NO. N00014-91-C-0222

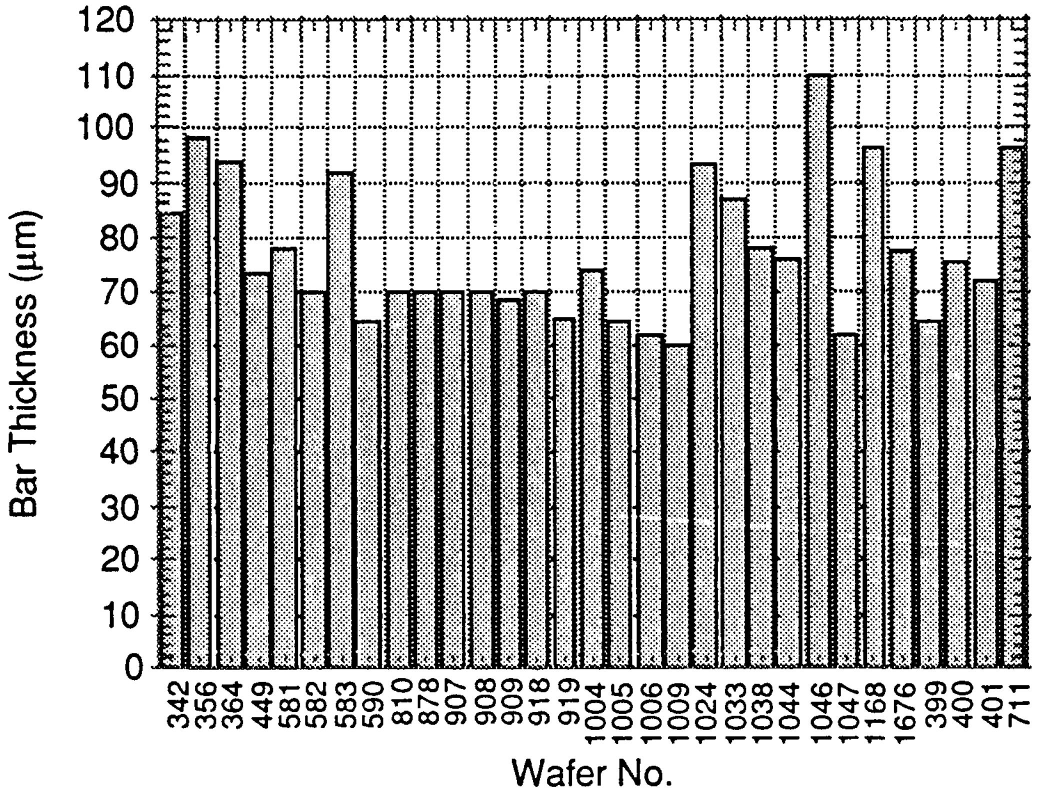
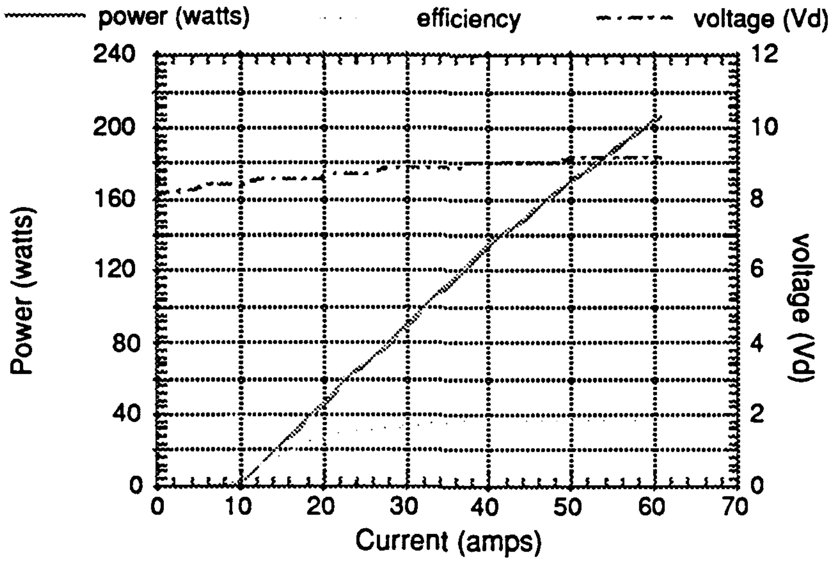
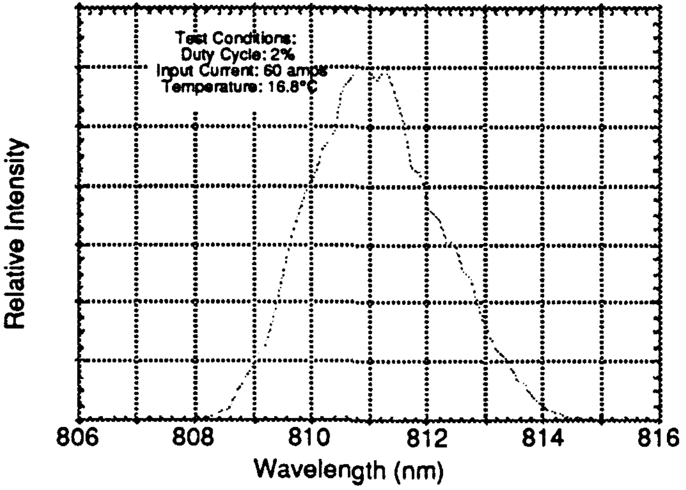


FIGURE #2 LASER DIODE BAR THICKNESS VARIATION
CONTRACT NO. N00014-91-C-0222

## Y11 ONR 582 5-Bar Side-Cooled Stack
## Contract No. N00014-C-91-0222



Spectral Measurement



Test Conditions:
Duty Cycle: 2%
Input Current: 60 amps
Temperature: 16.8°C

2.0% DUTY CYCLE; 200μsec/100Hz

FIGURE #3 Y11 ONR 5-BAR SIDE COOLED ARRAY
CONTRACT NO. N00014-91-C-0222