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MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING FOR NEODYMIUM --ETC(U)
JAN 78 D DENTZ DAAB07-77-C-0375

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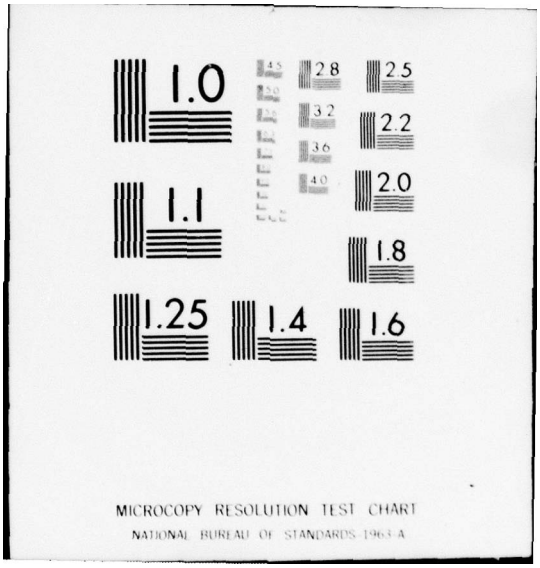
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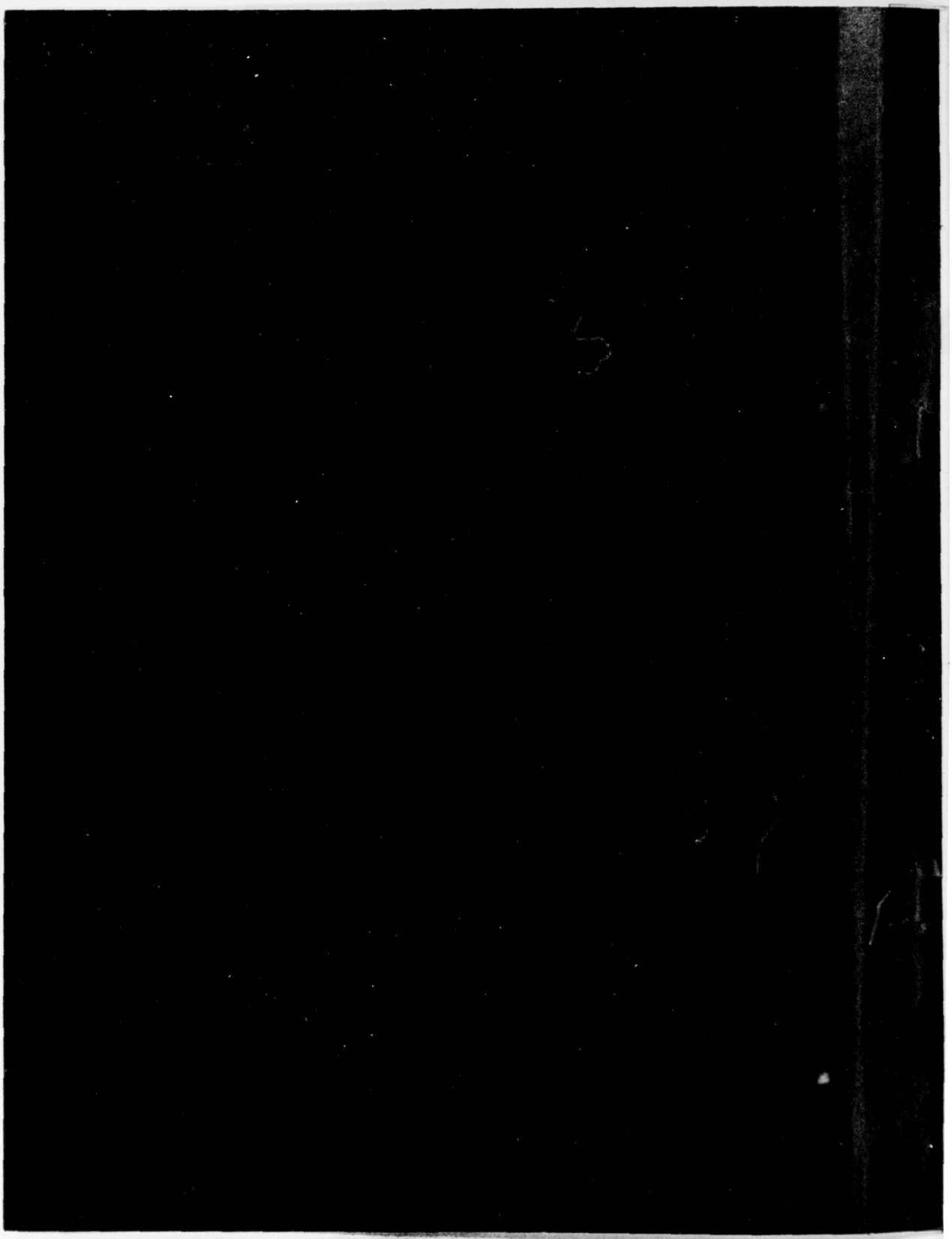

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Manufacturing Methods and Technology Engineering for Neodymium Doped YAG Laser Rods

D. Dentz

Third Quarterly Progress Report
September 1, 1977 to November 30, 1977

Contract No. DAABO7-77-C-0375

The objective of this program is to develop the production engineering techniques for multiple rod fabrication of Nd:YAG laser materials to a set of specifications typical of a system rod.

ABSTRACT

Additional polishing runs using the sixteen rod fixture were completed during this quarter. The polishing process previously developed was used with parallelism being obtained through dimensional control rather than interferometric monitoring. Work was begun to determine the influence of the fixture and mounting technique on rod end face parallelism.

TABLE OF CONTENTS

LIST OF TABLES

PURPOSE

The purpose of this production engineering program is to develop the mechanical and optical processes for multiple rod fabrication of neodymium doped YAG laser material. Control of quality is to be obtained through test procedures designed to meet the specifications of a typical system rod.

1.0 INTRODUCTION

During this quarter the tentative process for fabrication of laser rods was further defined. The fixture and polishing equipment used have been discussed in previous quarterly reports. The fixture is designed to hold sixteen rods during processing of both ends. Information was also developed on parallelism and the effects of the block and mounting technique on parallelism.

In the following sections the details of the tentative process are given. This process will be used in the fabrication of the Engineering Sample Laser Rods during the next quarter. The results achieved with this process in a trial run and the results of the experiments on the changes in parallelism observed after dismounting of rods are also discussed.

2.0 EQUIPMENT AND TOOLING

The tooling for this program consists of a polishing fixture designed to hold sixteen (16) 4.27 mm by 43 mm laser rods during the grinding and polishing operations. The rods are held in bushings and the block has been toleranced such that the required parallelism and perpendicularily specifications of 20 seconds and 5 minutes can be achieved. The details of the fixture design are given on pages 3 and 4 of the First Quarterly Progress Report.

The polishing equipment has been custom built for laser rod polishing. No modifications in equipment were made for polishing blocks of rods. The details of the work station are given in the First Quarterly Report.

3.0 MANUFACTURING PROCESS

3.1 Input Material

The input material to the final grinding and polishing operations are rods of neodymium doped yttrium aluminum garnet (YAG). The dopant level

is 1.0-1.3 atomic weight percent neodymium. The rough rods of material are 4.27 mm in diameter and 43.25 to 45 mm in length. The diameter is that required for the finished rod and the range of lengths provides sufficient material to be removed during the grinding and polishing operations. Leaving too much material on the rough rods is to be avoided as prolonged grinding times would result.

3.2 Mounting

In preparation for the grinding and polishing operations 16 rods are placed in the block. This assembly is heated on a hot plate until the wax flows freely when placed on the rods. The outside diameter of the rods is then coated with wax and the block is placed on a flat glass with the rods in a vertical position and allowed to cool. The rods are then lightly ground such that they will present a flat surface during the final finishing operations.

In the following sections the tentative manufacturing process is presented. Only after the Engineering Samples have been accepted will the process be adopted. Some modification may take place as the program progresses.

3.3 Twenty micron grinding

3.3.1 Select proper lap, marked grinding, and clean thoroughly using a mild detergent and water.

3.3.2 Clean polishing machine to make sure all residual polishing compounds from previous operations are removed.

3.3.3 Using spheometer measure lap - if not flat grind lap using 20 μ Al_2O_3 until flat. Install lap on polishing machine along with protective plastic ring.

3.3.4 Using comparator measure length of rods in block at several positions.

3.3.5 Apply 50 grams of Al_2O_3 to lap and add 50 ml of water. Mix until slurry is formed and distribute over lap.

3.3.6 Using timer set proper lap rotation rate - 8 rpm.

3.3.7 Place block of rods on lap and apply 80 strokes rotating block by 90° after each 20 strokes.

3.3.8 Remove block from lap and measure length and check surface finish. If grinding marks remain or rods are not working evenly replace block on lap.

3.3.9 Continue grinding until a 20 μ surface finish is obtained and rods are being evenly worked (no point to point variation in rod length). Additional water can be added to the slurry to maintain the proper consistency. Approximately 0.002 inches is removed during this process.

3.3.10 After completing run clean block and lap thoroughly using a mild detergent and water.

3.4 Twelve micron grinding

3.4.1 Repeat step 3.3.1 through 3.3.4 as required.

3.4.2 Apply 40 grams of Al_2O_3 to lap and add 40 ml of water. Mix until slurry is formed and distribute over lap.

3.4.3 Using timer set lap rotation rate of 8 rpm.

3.4.4 Place block on lap and apply approximately 80 strokes rotating block by 90° after each 20 strokes.

3.4.5 Remove block from lap, clean, measure lengths and check surface finishes. If proper surface finish has not been

obtained or all block positions are not of equal lengths - return block to lap and continue grinding.

3.4.6 During grinding it may be necessary to apply more pressure to one side of the block than the other to get all rods of equal length. Higher lap rotation rates may be used during these operations.

3.4.7 When 12 micron finish is obtained and all rods are working evenly remove block and proceed to next step.

3.5 Five micron grinding

3.5.1 Repeat steps 3.3.1 through 3.3.4 to assure that lap and block are properly cleaned.

3.5.2 Apply 25 grams of 5 μ Al_2O_3 to lap and add 40 ml of water. Mix to form slurry and distribute evenly over surface of lap.

3.5.3 Using timer set lap rotation rate to 8 rpm.

3.5.4 Place block on lap and grind for approximately 400 strokes. This should take about 5 minutes. Again an equal amount of time should be spent in grinding in each of four positions 90° apart. The rod end faces are checked to make sure a 5 μ finish is obtained. The processing time is nominal since surface finish determines when processing is complete.

3.5.5 When proper surface finish is obtained clean block and tools using detergent and water and proceed to the polishing process.

3.6 One micron polishing

3.6.1 Select proper lap, marked polishing, and clean thoroughly using detergent and water.

3.6.2 Clean work station to remove any residual polishing compounds from previous polishing steps.

3.6.3 Measure rod lengths using comparator. From this point on the polishing feet should be used for indication to avoid any damage to rod end faces.

3.6.4 Prepare slurry on lap mixing 10 grams of 1 micron Al_2O_3 to 50 ml of water. Approximate 5 ml of a suspension agent are added to reduce aglomerates. The slurry is mixed and spread evenly over the lap.

3.6.5 Using time set lap rotation rate of 8 rpm.

3.6.6 Place block on lap and polish for 400 strokes rotating block by 90° after each 100 strokes.

3.6.7 Remove block from lap, clean and inspect surface finish. If pits and scratches remain return to lap and repeat step 3.6.6 adding additional water to slurry as required.

3.6.8 Continue polishing and inspecting until a surface finish free of pits is obtained and desired flatness achieved. Some scratches will remain at this point. The parts are now ready for the next step.

3.7 0.3 micron polishing

3.7.1 Repeat steps 3.6.1 through 3.6.3.

3.7.2 Prepare slurry by mixing one gram of 0.3 μ Al_2O_3 and 50 ml of water. Mix slurry and distribute evenly over lap.

3.7.3 Using timer set lap rotation rate at 8 rpm.

3.7.4 Place block on lap and polish for 400 strokes rotating block by 90° after each 100 strokes.

3.7.5 Remove block from lap, clean and inspect surface finish. If scratching remains in excess of specification return to lap and continue polishing. Additional water can be added to the slurry as required to maintain proper consistency.

3.7.6 Do not contact rod end faces during inspection as scratching may result.

3.7.7 Continue polishing and inspecting until specified surface finish is obtained. Rods are then cleaned and readied for second end grinding and polishing.

3.9 Second end processing

3.8.1 Install cover on block to prevent any damage to rod end faces already polished.

3.8.2 Repeat grinding and polishing operations as outlined in paragraphs 3.3 through 3.7.

3.8.3 In step 3.6.7 check rod end face parallelism using Fizeau interferometer.

3.8.4 When second ends are finished the block is thoroughly cleaned and rods are dismounted by heating the block on a hot plate until the wax softens and rods are easily slipped out.

3.8.5 Rods are cleaned of residual wax, packaged and submitted for further testing.

4.0 DATA AND ANALYSIS

During this quarter a second run was made in which both ends of a block of sixteen rods were polished. The results obtained with respect to the critical specifications of perpendicularity, flatness, surface finish, and parallelism are shown in Table I. Parallelism data is reported for before and after rods were dismounted from the block. As can be seen from the table no problems were encountered in meeting the required specifications on perpendicularity (5 minutes) flatness (0.2λ) and surface finish.

Before dismounting, parallelism on all rods was well within specification (20 sec.). After dismounting three of the rods exceeded this specification and another 6 rods measured between 15 and 20 seconds. The change in parallelism ranged from zero to as much as 16 seconds. However, overall yield was 13 of 16 rods processed and exceeded the 12 rods required to meet the design goal of the process.

To investigate the effects of the block and mounting process on parallelism, the parallelism of the rods was measured unmounted, in the block, and heated on a hot plate and waxed into position. The results of this work is shown in Table II. The parallelism did not change when rods were slipped into position in the block. This indicated that the block itself is not stressing the rods. Once mounted however parallelism did change.

In an effort to minimize the change experienced a second experiment was conducted using an oven to mount the rods. The results of this are shown in Table III. The rods and block were heated in an oven and then waxed into position. Temperature was then allowed to stabilize and the

TABLE I

Specification Achieved - Double End Polishing

Position	Perpendicularity (min.)	Flatness (λ)	Surface Finish (Better than 20-5)	Parallelism (sec.) Before	After	Change
1	2.5	.1	yes	<10	17	7
2	3.0	.1	yes	<10	17	7
3	2.0	.1	yes	<10	<10	-
4	1.0	.1	yes	<10	26	16
5	3.0	.1	yes	<10	<10	-
6	2.0	.1	yes	<10	17	7
7	1.0	.1	yes	<10	<10	-
8	1.0	.1	yes	<10	<10	-
9	1.0	.1	yes	13	17	4
10	2.5	.1	yes	<10	<10	-
11	2.5	.1	yes	<10	13	3
12	1.5	.1	yes	<10	22	12
13	3.0	.1	yes	13	17	4
14	1.5	.1	yes	<10	13	3
15	3.0	.1	yes	<10	26	16
16	1.5	.1	yes	13	17	4

TABLE II

Parallelism of Unmounted and Mounted Rods

Rod No.	Position No.	Parallelism (sec.) Unmounted	In position not waxed	Waxed	Change
7073	15	11	11	13	2
7072	10	11	11	18	7
7075	12	11	11	10	1
7063	7	20	20	19	1
7068	6	9	9	9	-
7060	4	24	24	36	12

TABLE III

Parallelism - Oven Mounting

Position No.	Parallelism Before (sec.)	Parallelism After Mounting (sec.)	Change (sec.)
1	12	30	18
2	10	15	5
3	20	35	15
4	20	16	4
5	12	18	6
6	11	13	2
7	11	11	-
8	10	10	-
9	15	30	15
10	15	21	6
11	26	40	14
12	10	30	20
13	9	15	6
14	13	16	3
15	9	31	22

entire assembly was slow cooled. Changes in parallelism were still significant with over one third of the rods changing by more than 10 seconds. Additional experiments in this area will be necessary in an effort to minimize these changes.

5.0 CONCLUSIONS

Results of the polishing run conducted during this quarter were again excellent. Thirteen of the sixteen rods processed met required specifications on parallelism, perpendicularity, flatness and surface finish. No major difficulties were encountered in processing rods. This would indicate the work should proceed well on fabrication of Engineering Sample Rods during the next quarter.

The problem encountered with parallelism changing upon dismounting of rods must be investigated further. It is not effecting yield sufficiently to be considered a major difficulty but is a minor problem that will be addressed.

6.0 PROGRAM FOR NEXT QUARTER

During the next quarter experiments on mounting techniques will continue. Further evaluation of oven mounting proceedures will be made and different mounting waxes will be evaluated.

The Engineering Sample Laser Rods will be processed during the coming quarter. The process will be as outlined in this report. Testing of the rods will then be in accordance with the specifications as contained in SCS-507.

7.0 IDENTIFICATION OF PERSONNEL

The following is a list of the engineering and manufacturing personnel who contributed to the program during this quarter.

Engineers and Technicians	Hours this Quarter	Cumulative Hours
Dentz, D.	170	450
Turner, S.	20	100
Belt, R.	10	45
Lowe, I.	10	45
O'Neill, J.	30	80
Manufacturing	30	105
TOTALS	270	825