

TARDEC

---TECHNICAL REPORT---

THE NATION'S LABORATORY FOR ADVANCED AUTOMOTIVE TECHNOLOGY

No. 13766



WINNER OF THE 1995 PRESIDENTIAL AWARD FOR QUALITY

Laser Damage Testing of Molybdenum Shutter

May 1999

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REPORT DOCUMENTATION PAGE

Form Approved
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|--|---|--|--|--|
| 1. AGENCY USE ONLY (Leave blank) | | 2. REPORT DATE May 1999 | 3. REPORT TYPE AND DATES COVERED Technical Report | |
| 4. TITLE AND SUBTITLE Laser Damage Testing of Molybdenum Shutter | | | 5. FUNDING NUMBERS | |
| 6. AUTHOR(S) Thomas A. Whittaker, Robert V. Goedert, and Andrew F. Clements | | | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army TACOM, TARDEC AMSTA-TR-R (MS 263) Warren, MI 48397-5000 | | | 8. PERFORMING ORGANIZATION REPORT NUMBER TARDEC Technical Report No. 13766 | |
| 9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army TACOM, TARDEC AMSTA-TR-R (MS 263) Warren, MI 48397-5000 | | | 10. SPONSORING / MONITORING AGENCY REPORT NUMBER TARDEC Technical Report No. 13766 | |
| 11. SUPPLEMENTARY NOTES | | | | |
| 12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release: Distribution is unlimited | | | | 12b. DISTRIBUTION CODE A |
| 13. ABSTRACT (Maximum 200 Words) This technical report presents the data collected from in-house laboratory testing of a Molybdenum shutter. Laser damage testing was performed on the sample using a Q-switched, frequency doubled Nd:YAG laser to determine the laser induced damage threshold of the material under typical operating conditions. | | | | |
| 14. SUBJECT TERMS Laser damage testing, Nd:YAG laser, Molybdenum, laser shutter | | | | 15. NUMBER OF PAGES |
| | | | | 16. PRICE CODE |
| 17. SECURITY CLASSIFICATION OF REPORT Unclassified | 18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified | 19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified | 20. LIMITATION OF ABSTRACT Unlimited | |

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1.0 SUMMARY

This technical report presents the data collected from in-house laboratory testing of a .004" thick Molybdenum shutter. Laser damaging testing was performed on the sample using a Q-switched, frequency doubled Nd:YAG laser to determine the laser-induced damage threshold of the material under typical operating conditions. A total of eighteen sites were each exposed to 600 laser pulses. The laser was fired at a repetition rate of 10 Hz for a duration of 1 minute.

Test results show that the Molybdenum sample will damage when exposed to multiple laser pulses with fluences greater than or equal to 0.19 J/cm^2 . Results also showed that as the fluence increased the damaged area increased.

The authors recommend that this type of Molybdenum sample not be used as a shutter for TARDEC's Continuum Powerlite Nd:YAG laser because the sample will damage under typical operating conditions.

2.0 INTRODUCTION

The Emerging Technologies Team is searching for a fast, mechanical, external shutter for TARDEC's Continuum Powerlite Nd:YAG laser. A .004" thick Molybdenum sample was acquired from Vincent Associates as a potential shutter. A laser damage test was performed on the sample to determine if this material could function as a shutter for our application without damaging.

3.0 LASER DAMAGING TESTING

3.1 Test Description: Laser damaging testing was performed on the sample using a frequency doubled Nd:YAG laser to determine the laser-induced damage threshold of the material under typical operating conditions. The laser was operating in near TEM₀₀ mode with a 10-16ns pulse length. A total of eighteen sites were each exposed to 600 laser pulses. The laser was fired at a repetition rate of 10 Hz for a duration of 1 minute. Each site was exposed to a constant fluence level, but this fluence level was varied from site to site and ranged from 0.1 J/cm^2 to 1.8 J/cm^2 . The mirrored surface of the sample was exposed in a grid pattern with each site separated by 2.5 mm. After each site was exposed to the multiple shots, the sites were examined to determine if damage occurred. This examination was done with the naked eye and under a microscope.

3.2 Test Equipment:

- Continuum Q-switched Nd:YAG Laser
- Laser Probe Silicon Energy Detector, Model No. RJP-765 a
- Laser Probe Silicon Energy Detector, Model No. RJP-765 a
- Laser Probe RM-6600 Universal Radiometer

NIST Calibrated Neutral Density Filters

3.3 Experimental Arrangement: See Figure 1.

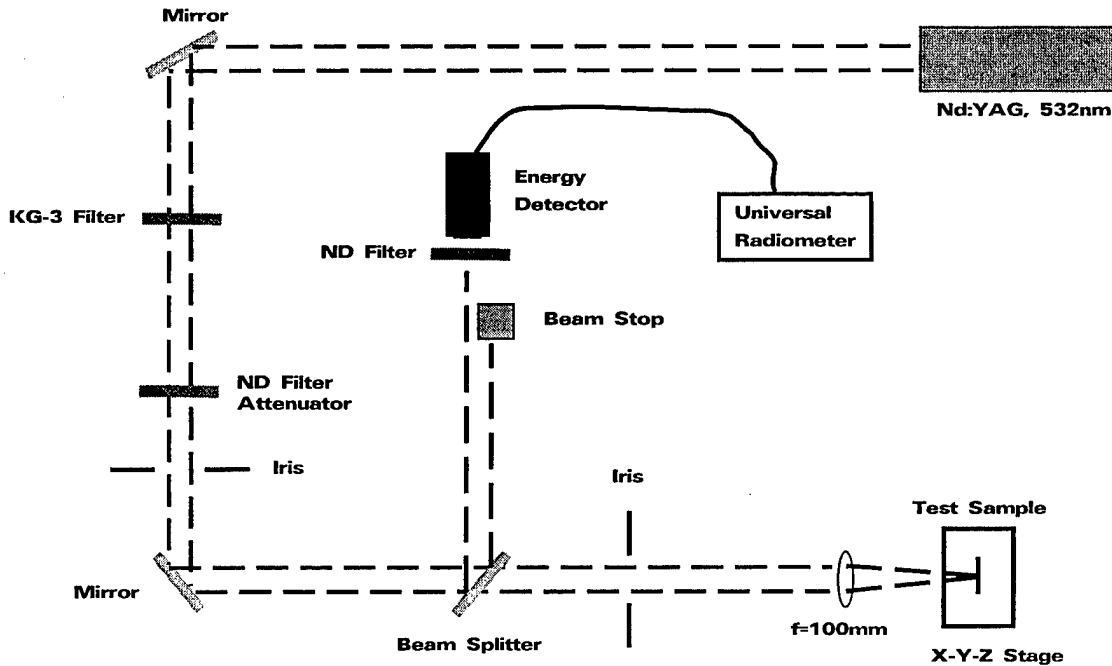


Figure 1. Experimental Arrangement

3.4 Spot Size Determination: The laser beam was focused onto the test sample with a plano-convex lens (40 mm diameter, $f=100$ mm). The $f/\#$ of this set-up was approximately 41. In order to determine the fluence level for each exposed site, it was necessary to

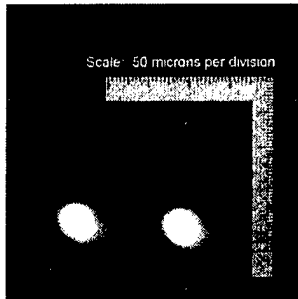


Figure 2. Spot Size at Sample

determine the spot size of the laser beam at the sample. This was accomplished by placing burn paper in the plane of the sample and recording a laser burn (see Figure 2). The burns were then examined under a microscope to determine their size. The spot diameter at the sample was determined to be $435\mu\text{m} \times 585\mu\text{m}$ or an average of $510\mu\text{m}$.

4.0 OBSERVATIONS/RESULTS

4.1 A summary of the laser damage test results for the Molybdenum shutter is presented in Table 1. Figure 3 shows the test sample after it had been tested. Figure 4 provides a close-up of the test sites showing a grid pattern. The circles in the figure show the sites that were not damaged. The scale shown at left of the figure is 1 millimeter/division.

| Site Number | Input Energy (mJ) | Fluence (J/cm ²) | Damage |
|-------------|-------------------|------------------------------|--------|
| 1 | 3.22 | 1.57 | Yes |
| 2 | 0.26 | 0.13 | No |
| 3 | 0.85 | 0.42 | Yes |
| 4 | 1.76 | 0.86 | Yes |
| 5 | 3.47 | 1.70 | Yes |
| 6 | 2.43 | 1.19 | Yes |
| 7 | 2.44 | 1.19 | Yes |
| 8 | 1.83 | 0.90 | Yes |
| 9 | 0.95 | 0.47 | Yes |
| 10 | 0.39 | 0.19 | Yes |
| 11 | 0.38 | 0.19 | Yes |
| 12 | 3.38 | 1.66 | Yes |
| 13 | 3.69 | 1.81 | Yes |
| 14 | 0.28 | 0.14 | No |
| 15 | 3.46 | 1.69 | Yes |
| 16 | 0.27 | 0.13 | No |
| 17 | 3.47 | 1.70 | Yes |
| 18 | 0.20 | 0.10 | No |

Table 1. Summary of Test Results

4.2 The multiple shot laser-induced damage threshold for the Molybdenum test sample was 0.19 J/cm².

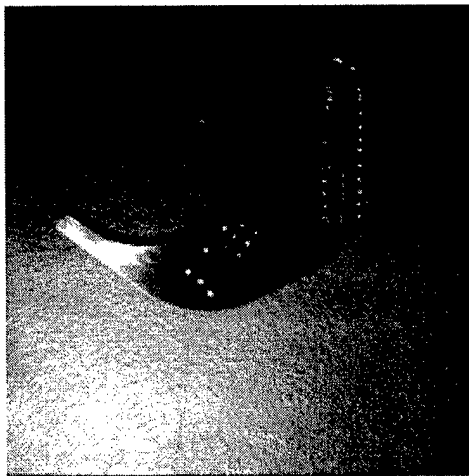


Figure 3. Molybdenum Test Sample

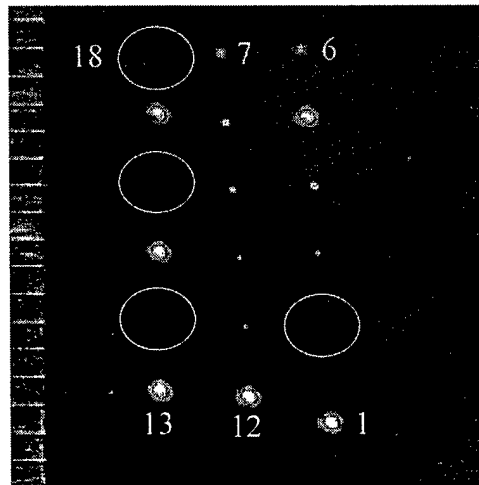


Figure 4. Magnified Test Sites

4.3 While testing the Molybdenum sample we noted that the damaged area increased as the fluence increased. This is illustrated in Figure 5. We also determined that the damage spot size increase is directly related to the increase in input fluence. For example: for site 15 the fluence was 1.69 J/cm² and the area of the damage spot was 159

mm² and for site 10 the fluence was 0.19 J/cm² and the area of the damage spot was 0.0177 mm² (see Figure 6). The ratio of the two site's fluences (8.90) and damage spot areas (8.98) was nearly identical.

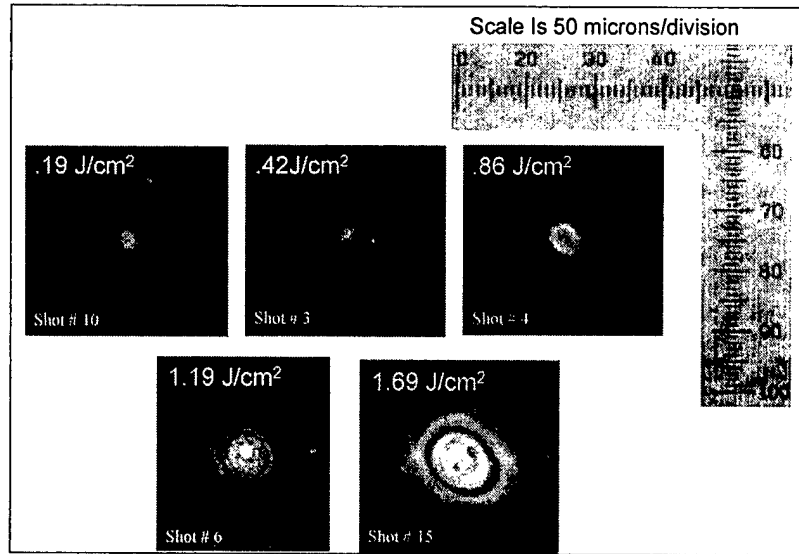


Figure 5. Damage with Increasing Fluence

4.4 After examining the damage sites, it was apparent that several of the damage sites had a ring or halo surrounding the primary elliptical damage site. This effect was seen for input fluences greater than or equal to 1.19 J/cm². It was postulated that this ring was caused by a laser-induced shockwave. The ring may be the result of a shock propagating out from the center of the damage site, ejecting coating material at the peak of the first crest. The dark ring may be coating left intact at the first minimum.

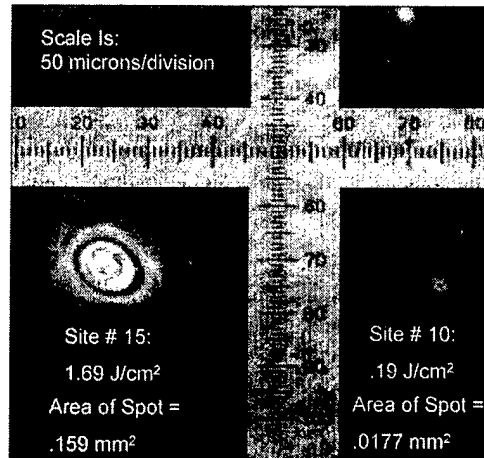


Figure 6. Comparison of Damage Spot Areas

5.0 CONCLUSIONS

5.1 Laser damaging testing was performed on the sample using a frequency doubled Nd:YAG laser to determine the laser-induced damage threshold of the material under typical operating conditions.

5.2 Test results show that the Molybdenum sample will damage when exposed to fluences greater than or equal to 0.19 J/cm^2 . Results also showed that as the fluence increased the damaged area increased.

6.0 RECOMMENDATIONS

6.1 We recommend that this type of Molybdenum sample not be used as a shutter for TARDEC's Continuum Powerlite Nd:YAG laser because the sample will damage under typical operating conditions.

6.2 We recommend that other alternative materials be pursued for this application.

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