# QUALIFICATION OF LASER DIODE ARRAYS FOR MERCURY LASER ALTIMETER

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## ABSTRACT

NASA's requirements for high reliability, high performance satellite laser instruments have driven the investigation of many critical components; specifically, 808 nm laser diode array (LDA) pump devices. Performance of Quasi-CW, High-power, laser diode arrays under extended use is presented. We report the optical power over several hundred million pulse operation and the effect of power cycling and temperature cycling of the laser diode arrays. Data on the initial characterization of the devices is also presented.

## 1. INTRODUCTION

The MESSENGER [1] mission is flying the Mercury Laser Altimeter (MLA) [2] which is a diode-pumped Nd:YAG laser instrument designed to map the topography of Mercury.

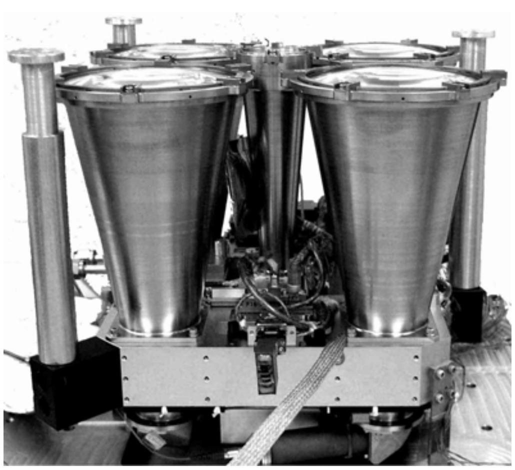


Figure 1 – MLA instrument diagram illustrating four receiver telescopes and single, central transmitter telescope.

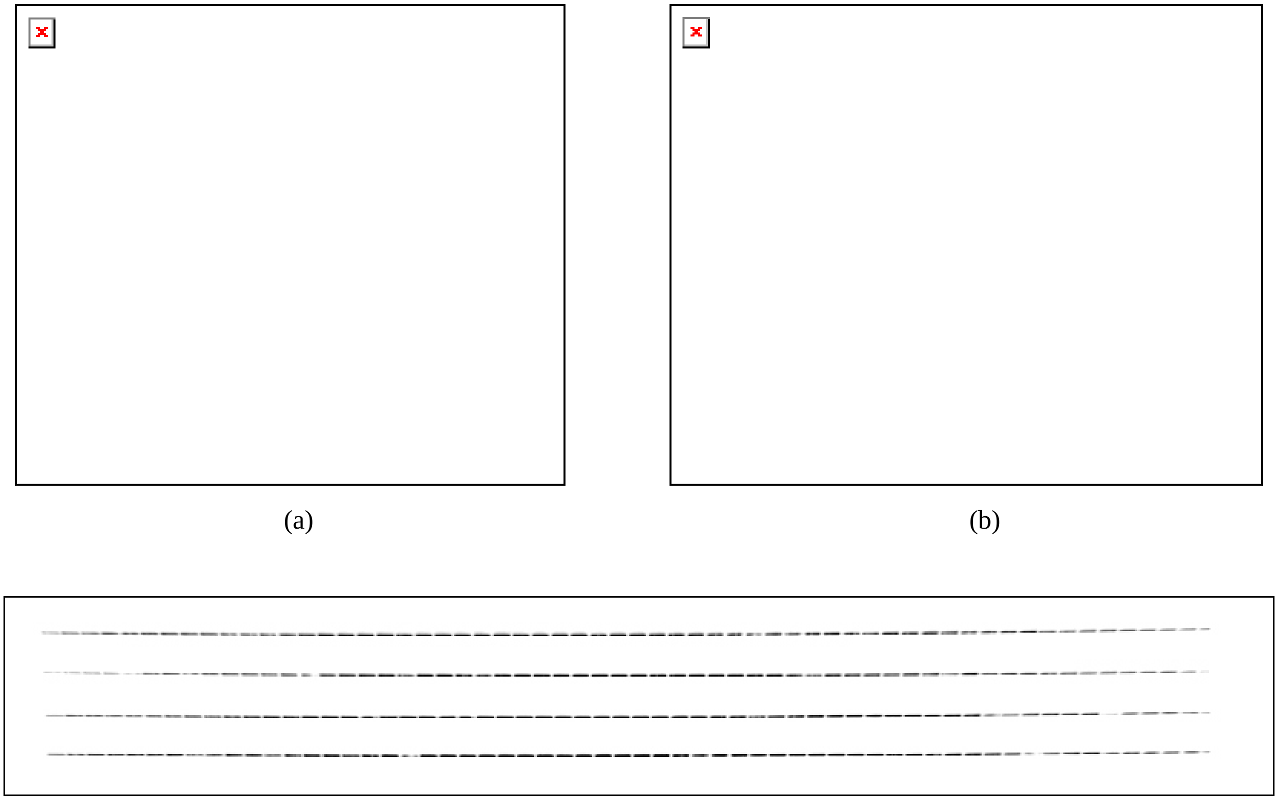
MESSENGER is scheduled to launch from Kennedy Space Center in July of 2004 aboard a Delta 2 Rocket. The environment imposed on the instrument by the orbital dynamics places special requirements on the laser diode arrays. In order to limit the radiative heating of the satellite from the surface of Mercury, the satellite is designed to have a highly elliptical orbit. The satellite will heat near perigee and cool near apogee. The laser power is cycled during these orbits so that the laser is on for only 30 minutes (perigee) in a 12-hour orbit. The laser heats 10°C while powered up and cools while powered down. In order to simulate these operational conditions, we designed a test to measure the LDA performance while being temperature and power cycled.

Though some of the mission requirements are specific to NASA and performance requirements are derived from unique operating conditions, the results are general and widely applicable. Since a great many LIDAR systems employ diode-pumped solid-state lasers, it is critical that these components be robust and reliable. Laser diode arrays are used in a great many LIDAR applications and understanding their performance will enable much better engineering trades to optimize performance for the specific application.

## 2. MEASUREMENTS

NASA's requirements for high reliability, high performance satellite laser instruments have driven the investigation of many critical laser components. [3] Specifically, 808 nm laser diode array (LDA) pump devices are being investigated. We present results on the performance of twelve LDAs operating for several hundred million pulses. The arrays are 100 watt, quasi-CW, conductively cooled, 808 nm devices. Prior to testing, we fully characterize each device to establish a baseline for individual array performance and status.

We measure the average optical spectrum, optical power and efficiency vs. input current and the near field. We also measure the thermal profile using infrared imaging (3-5 microns) of LDA. Fig. 1 illustrates some representative data of an initial characterization. Periodically through the testing, the arrays are characterized again. Further details of this characterization can be found in [4].



(a) (b)

(c)

Figure 2 – (a) Power and efficiency vs. current (b) average optical emission spectrum (Arb. Units) and (c) near field image for a 4-bar laser diode array

All LDAs operate at 30 Hz frequency with a duty cycle of 0.6%. The 200 µs electrical pulses have an amplitude of 100 amps. The test is conducted in a laminar flow environment. LDAs are divided into four groups and subjected to the temperature and power cycling matrix shown in Table 1. The matrix was designed to see the effect of both simultaneous temperature and power cycling as well as decouple one effect from the other.

Table 1. – Testing matrix showing the varying operational conditions of the laser diode arrays.

| | **Constant Power** | **Cycled Power** |
|---|---|---|
| **Constant Temperature** | 2 G2's & 2 G4's | 2 G4's |
| **Cycled Temperature** | 2 G4's | 2 G2's & 2 G4's |

The temperature and power cycling pattern is illustrated in Fig. 1. The temperature cycles over a 10°C range every hour. The power is cycled over the same interval.

During testing, we continuously measure current, voltage, efficiency, optical power and temperature of each LDA. Present results of the optical power are shown in Fig. 3.

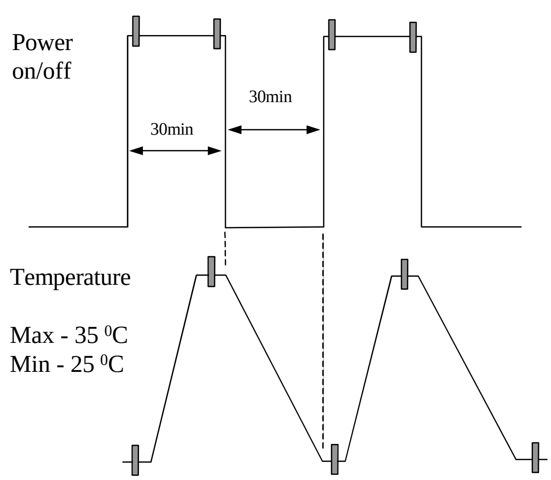



Figure 3. - Laser diode array power and temperature cycle.

The data shows little or no degradation for 11 of the LDAs after near-continuous operation at 30 Hz for over 6 months.. The power cycled LDAs have accumulated nearly 200 million pulses while the constant power devices have accumulated over 400 million pulses. One LDA (D12) failed completely after 160 million pulses. It is important to note that the failure of D12 may have been found with an extended burn-in because one bar of the four-bar array failed after 10 million pulses. This affect can be seen by a 25% drop in power at 10 million pulses. This is corroborated by a near field image like Fig. 1. (c) (not shown in this paper.) The ability to screen for poor performing bars is important as it will enable identification of more reliable LDAs. The failure mechanism of device D12 is currently under investigation.

During this test the cycled arrays have been exposed to more than 3,500 power and temperature cycles.

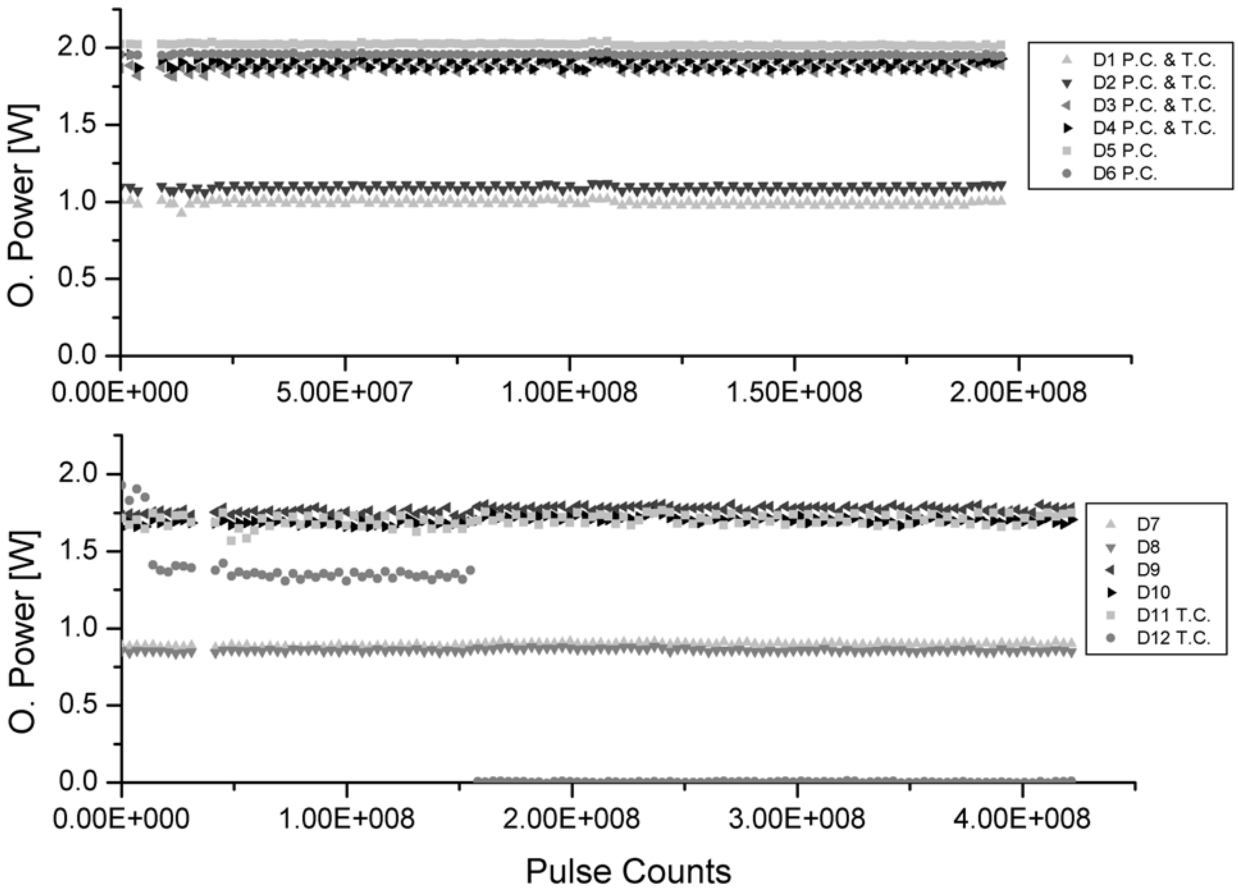



Figure 4. - Lifetime test data. Optical Power vs. pulse counts. P.C. - power cycling, T.C. - temperature cycling

## 3. CONCLUSIONS

Operation for 6 months and 400 million pulses without degradation is extremely promising for reliability of LIDAR instruments. In the push to get instruments out of the lab and into the field, long-term performance data will become increasingly necessary. The work shown here is part of a NASA program working to improve the reliability and performance of laser instruments in space platforms. This work will continue, not only to quantify LDA performance but also improve reliability and find parameters to screen for possible poor performing devices.

Despite MLA's harsh operational environment, the lifetime requirement is fairly conservative - only needing 30 million pulses and one thousand thermal and power cycles for mission success. So flight arrays performing as well as these will enable the instrument to meet its science specifications. This test continues to run so additional data will be available. Although many of NASA's requirements are unique, the desire for robust, high-reliability, high performance devices is universal.

## REFERENCES


1. http://messenger.jhuapl.edu

2. Sun, X., Cavanaugh, J. F., Smith, J. C., Bartels, A. E.; "Design and Performance of the Mercury Laser Altimeter" in *Conference on Lasers and Electro-Optics*, (2004)

3. Heaps, W. H., Novo-Gradac, A. M., "Progress on space-borne laser risk reduction" at the *22nd ILRC*, (2004)

4. Stephen, M.A., Vasilyev A., "Characterization of 808 nm Quasi-constant Wave Laser Diode Arrays" in *Earth Science Technology Conference*, (2003)