PROTON IRRADIATION TESTS OF LASERS FOR INSTRUMENTATION ON ICY MOON MISSIONS.

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Introduction: Missions designed to explore the surfaces of Europa and Enceladeus will need to contend with high levels of ionizing radiation including high energy protons, heavy ions, electrons, X-rays and gamma rays. For the current Europa Lander mission concept in formulation, a vault would be used to provide shielding for instruments and electronics within it. Despite this, a total fluence of 10^{11} protons/cm^2 is expected during the course of the planned 20 day surface mission [1]. Here we present test results describing the performance of two different types of diode-pumped solid-state (DPSS) lasers before and after proton exposure at this fluence. Proton radiation exposure is a serious concern since it can cause displacement damage to both passive[2, 3] and active components[4-6] within the lasers that could reducing the science return of a green in-situ Raman spectrometer for which they are being considered[7].

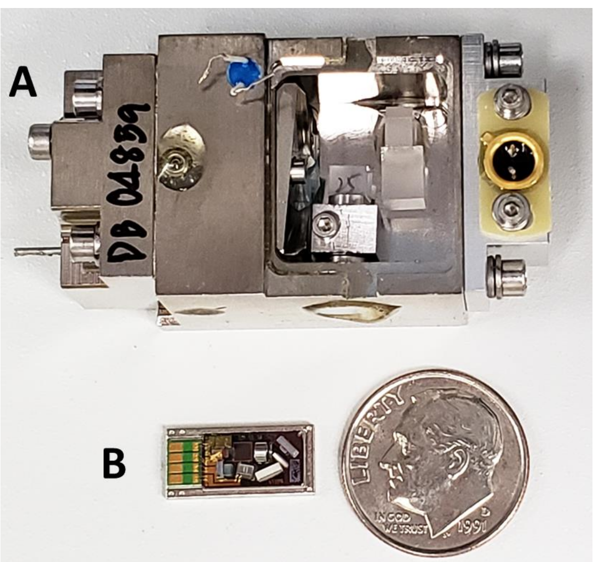

Figure 1A JDSU laser with TEC used in CIRS.
Figure 1B OSRAM laser

The first laser is a JDSU (now Lumentum) model CDS532M laser that produces a continuous wave, single frequency output beam. Internally, a 1W diode laser with an InGaAsP active regions on an GaAs substrate is used illuminate a Nd:YVO4 (vanadate) host crystal at 808nm. The vanadate forms one side of the laser's main cavity and in conjunction with the output coupler lases inside the cavity at 1064nm. An, intracavity KTP frequency doubling crystal is used to generate the green single-frequency output light at 532nm. A thermo electric cooler (TEC) under the plated copper housing of the device provides temperature control (see Figure 1a).

The OSRAM model PL 530 laser, originally developed for small pico-projectors before direct-diode green lasers became available turns out to be an ideal source for Raman spectroscopy because of its high wall -plug efficiency, very small size, and single frequency output. This laser generates a fundamental wavelength nominally at 1060nm using an optically pumped vertical external cavity surface emitting laser (VECSEL) that is intracavity doubled to a nominal wavelength of 530nm using a periodically-poled Lithium Niobate (PPLN) crystal[8]. An integral heater is used to raise the temperate of the PPLN crystal slightly allowing a quasi-phase matching condition to be satisfied necessary for efficient frequency doubling.

Laser	JDSU	OSRAM
Model	CDPS532M	PL530
Mass	107.3g	1.4g
Power (mW)	50	46-120
Beam diameter (mm)	0.6	0.1
Footprint (mm)	44.8 x 24.3	14.2 x 6.8

Table 1 JDSU and OSRAM laser comparison

Results: The JDSU laser showed markedly little change after undergoing irradiation. This laser was operated in constant current mode and tested for 30 minutes before and after exposure to measure variations in optical output power. The irradiation appears to have caused a small drop in average laser power (of the order of 2mW) (Figure 2) but the laser shows similar relative stability aside from the offset in power.

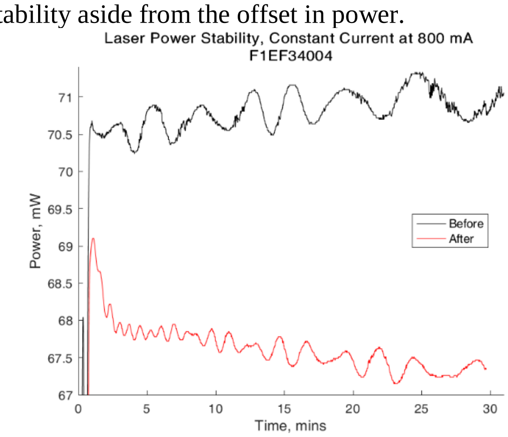

Figure 2 JDSU Laser power stability over time, before and after irradiation

During the initial boot up for the laser the power levels fluctuate before settling at 70.5mW initially and 68mW post irradiation. This fluctuation is consistent over multiple operations and shows little change after the laser was irradiated other than the previously noted 2mW drop in power (figure 3).

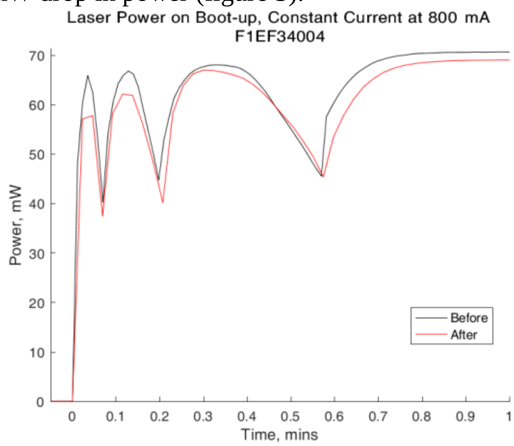

Figure 3 JDSU Laser power initial boot up, before and after irradiation

The frequency shift observed over changing temperatures running at a constant current of 800 mA followed the same trends before and after irradiation showing very little change, the same multi frequency effects occur at the same temperatures (figure 4).

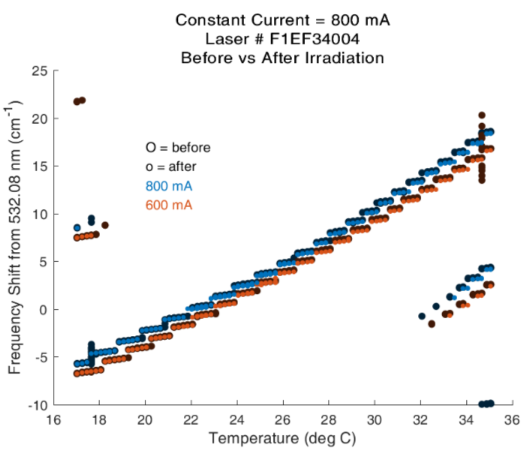

Figure 4 JDSU laser frequency shift with temperature change, before and after irradiation at 600 mA and 800 mA

The JDSU integrated TEC showed a more notable decline in response in comparison to prior to the radiation damage. Temperatures took longer to stabilize and overshot before returning to the required temperature. A higher current could have reduced this stabilization time, however current limiting the TEC prevents damage to the component (figure 5).

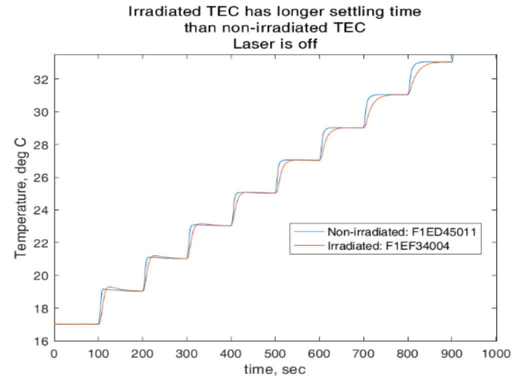

Figure 5 JDSU TEC temperature change over time

Analysis of the Osram laser also showed little changes. The voltage drop across the laser diode V/I curves showed only a slight change for 11C and 25C for pre and post irradiation (figure 6). This is similar to that of the JDSU laser. Laser performance is not impacted.

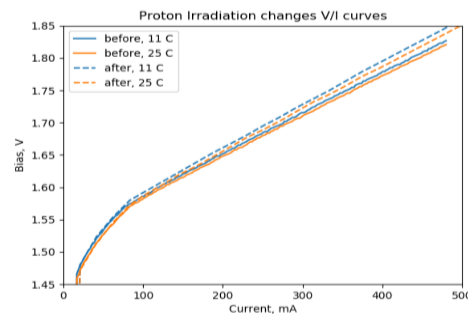

Figure 6 OSRAM laser V/I curves at 11C and 25C before and after irradiation

Conclusions: Both lasers showed little to no damage from exposure to the radiation source. The TEC integrated into the JDSU laser showed the largest difference. As such additional time should be allocated for the TEC to stabilize at the required temperature before commencing laser operations. As such the JDSU laser included within CIRS would be capable of operation for the duration of the full expected proton dose during a Europa lander mission.

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References: [1] NASA, Europa Lander Study 2016 Report (2016) *NASA*. [2] Naletto, G., et al., (2003) *Applied optics* [3] Gusarov, A.I., et al., (2002) *Applied optics*, [4] Barnes, C., et al., (2000). [5] Johnston, (2001) *IEEE Transactions on Nuclear Science*, [6] Paxton, A.H., et al., (1997) *IEEE Transactions on Nuclear Science* [7] Wang, A., B. Jolliff, and J. Lambert, (2014) *IPM* [8] Lindberg, H., et al,. (2011) *International Society for Optics and Photonics*