Radiation Resistance of the Single Frequency 1310-nm AlGaInAs-InP Grating-Outcoupled Surface-Emitting Laser

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Abstract— Two Single-frequency 1310-nm grating-outcoupled surface-emitting (GSE) semiconductor lasers have been exposed to the ionizing radiation using 200 MeV/c proton beams. The lasers survive the total radiation dose of 1.50 Mrad but fail after irradiation to integrated dose of 22.3 Mrad. The results indicate suitability of these laser to space and accelerator based particle physics applications.

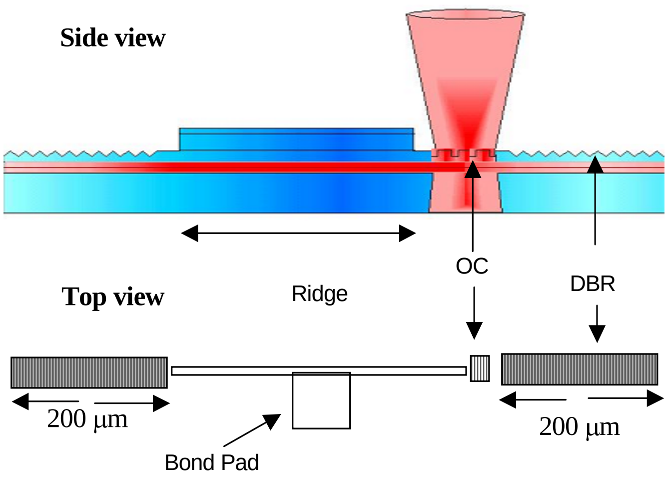
INTRODUCTION

Novel semiconductor lasers, based on the Grating-Outcoupled Surface-Emitting principle [1], have been developed by Photodigm, Inc. [2]. These lasers consist of a 500 μm long active ridges that excite one end of a surface emitting second-order outcoupling gratings with 200 μm long first-order DBR Gratings terminating the laser cavities at both ends. These lasers provide an attractive alternative to the commercially available devices and are well suited to optical interconnects and data links used in particle and nuclear physics experiments. Surface emission allows for complete wafer level processing and testing leading to a reduction in cost and to enormous increases in performance and reliability for electronic integrated circuits [3]. Furthermore, the geometrical arrangement of the lasers around a common grating allows for multiplexing of up to four different wavelengths with independent modulation into a single fiber. Such multiplexing will lead to a reduction of the number of the corresponding cable and fiber plant necessary for data transmission. A schematic drawing of a single wavelength GSE laser geometry is shown in Fig. 1.

In this letter, we report on the initial studies of the radiation resistance of the GSE lasers. Solid-state lasers are often used in the optical data links transmitting signals from particle detectors. In such detectors, e.g., in ATLAS at the Large Hadron Collider [4], the front-end readout electronics is located in the harsh radiation environment. For example, the read-out boards of the ATLAS Liquid Argon calorimeter subsystem must survive the integrated dose of 800 Gy of photons and 0.8 Gy of charged particle radiation over its 10 years of operations and must withstand the fluence of 1.7 x 10^{13} neutrons (1 MeV Si) per cm^2 of the components surface [5]. The CERN Laboratory is considering a future luminosity upgrade of the LHC with the projected rise of the radiation dose requirements by about a factor of 10.

Two lasers were exposed to a 200 MeV/c proton beam at the Indiana University Cyclotron Facility. The facility delivers a beam of protons with the tunable momentum in the range of 30 to 200 MeV/c and a 2 to 20 cm wide beam spot. For this study, the highest momentum range of 200 MeV/c was chosen to allow for the radiation exposure of all laser components. The average beam flux was 3.1×10^9 protons/cm^2/second.

Fig. 1. Side view and top view of GSE laser geometry.



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EXPERIMENTAL RESULTS AND DISCUSSION

The lasers were exposed in a passive, un-powered mode and received an integrated fluence of 2.69×10^{13} p/cm^2 and 4.0×10^{14} p/cm^2, respectively. These fluencies correspond to the total doses of 1.5 Mrad and 22.3 Mrad, respectively. The 1.5 Mrad dose corresponds to the highest total radiation exposure expected at ATLAS at the proposed LHC luminosity upgrade and represents a goal for all electronics components located on the detector. Following the exposure, there was a cooling period of 90 days before lasers were removed from the radiation chamber for shipment for testing. The comparison of the bias current and of the light output power before and after the irradiation with the two doses is shown in Figs.2-4. For the lower dose of 1.5 Mrad (Figs.2), we observe a small shift of the bias current and about 10% decrease of the light output at the same bias. The slope efficiency, however, remains unchanged allowing for error free operation of the laser. In contrast, the high radiation dose of 22.3 Mrad (Figs.3) appears be fatal to the operations of the GSE laser.

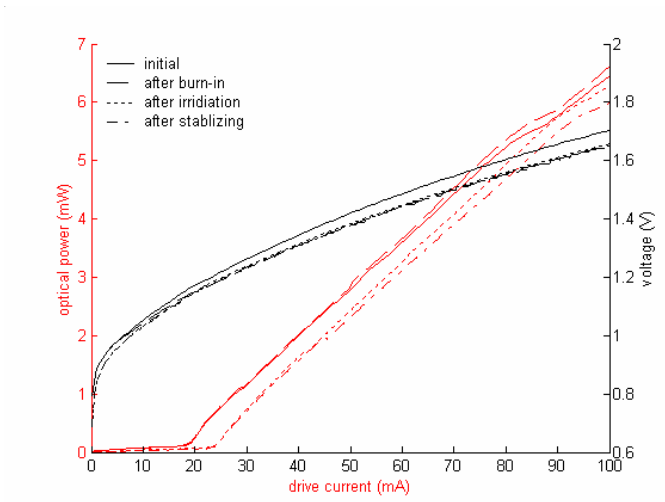

Fig. 2. The L-I-V curve of the laser that received 1.5 Mrad radiation dose.

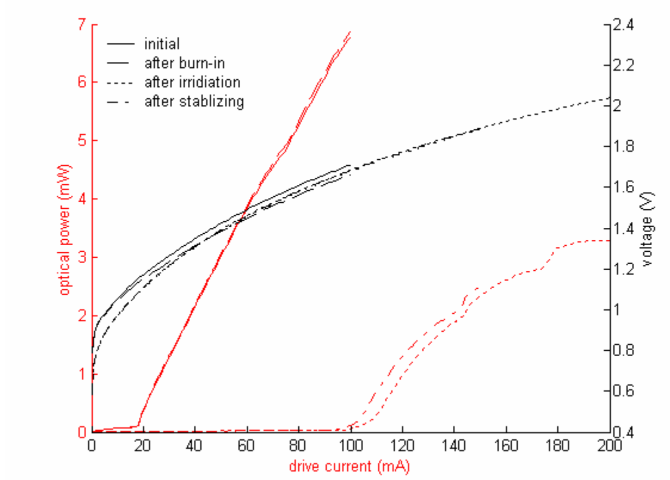

Fig. 3, The L-I-V curve of the laser that received 22.3 Mrad radiation dose.

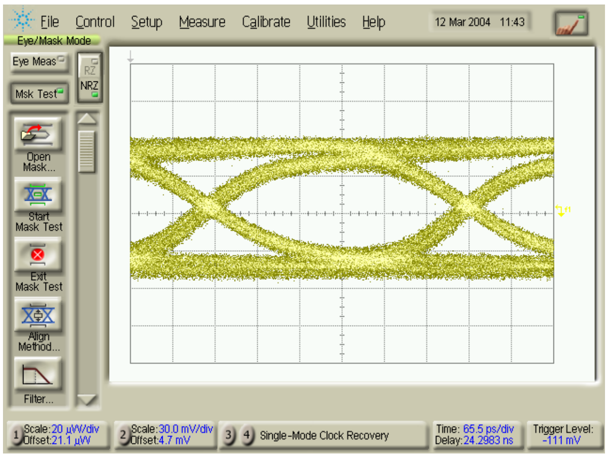

Fig. 4. Eye diagram at 2.5 Gb/s modulation after the irradiation with the 1.5 Mrad dose..

Fig. 4 shows an open eye diagram at 2.5 Gb/s after the total irradiation dose of 1.5 Mrad. The laser was driven by a nonreturn-to-zero, 2^{23}-1 back-to-back pseudorandom signal into a single mode fiber. The device was biased at 35mA and the modulation depth was 50mA. The measured rise time was 69ps and the fall time was 118ps. All performance parameters were consistent with those observed before irradiation.

CONCLUSIONS

GSE lasers perform well after the irradiation with the total dose of 1.5 Mrad that exceeds highest doses expected in space physics projects and at the upgraded Large Hadron Collider experiments. It fails before reaching the total dose of 22 Mrad.

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