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Radiation-Hard Optical Hybrid Board for the ATLAS Pixel Detector

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We have designed a hybrid board for optical data transmission in the ATLAS pixel detector. This opto-board features two kinds of ASICs, VDC and DORIC. The former drives a Vertical Cavity Surface Emitting Laser (VCSEL) for data transmission from the pixel detector and the latter recovers Bi-Phase Mark (BPM) encoded command signals received optically by a PIN diode. The opto-board is fabricated with a beryllium-oxide (BeO) substrate for heat management. We present the status of opto-board production and performance.

1. Introduction

In this report we describe the final results in development of optical hybrid boards as well as the tests used to measure its radiation hardness. The ATLAS pixel optical readout system contains 180 opto-baords carrying 448 VDC and 360 DORIC chips. The optical link circuitry will be exposed to a maximum total fluence of 10^{15} 1-MeV neq/cm^2 during ten years of operation. In this paper we describe the development of the radiation-hard optical hybrid boards for use in the ATLAS pixel detector's optical link.

2. Opto-Board

The VDCs, DORICs, and opto-packs are mounted on opto-boards. We produce opto-boards of two flavors with each opto-board serving six or seven modules. For outer barrel layer and the disk system each module requires one link for transmitting data, hence each opto-board contains two VDCs plus one VCSEL array opto-pack on the top side and two DORICs plus one PIN array opto-pack on the bottom side. The inner barrel (B) layer is expected to have a higher hit occupancy, requiring two links for transmitting data to the ROD. The top side hence contains four VDCs plus two VCSEL array opto-packs with each pair of links serving a module connected to adjacent fibers in an 8-fiber ribbon.

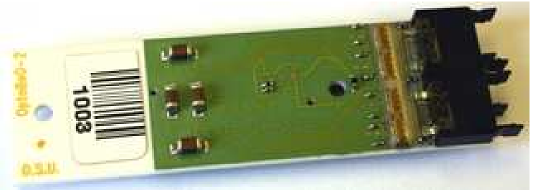

Fig. 1. Example of a populated BeO opto-board.

The opto-board is fabricated with beryllium oxide as the substrate for heat management. The top view of an assembled B-layer opto-board is shown in Figure 1. The bottom layout is the same for both opto-board flavors. We initially prototyped the opto-boards using FR-4 as the substrate for fast turnaround and cost saving. Four prototype runs were submitted to accommodate changes in the chips and opto-pack design. We had two prototype submissions with BeO. The first vendor produced opto-boards with many opens and shorts between traces. However, the second vendor [2] was able to produce opto-boards of high quality. We observed low PIN current thresholds for no bit errors when all links are active, indicating that there is no significant cross talk on the opto-boards.

3. Irradiation Studies

In our June 2004 irradiation four fully populated opto-boards were mounted in the shuttle setup, two at a time. The optical power and threshold for no bit errors were monitored in real time. The opto-boards were remotely moved in and out of the beam-line for annealing of the VCSEL's. In this setup pseudo-random BPM signals are generated in the control room and sent via 25m of optical fibers to VDCs and DORICs on opto-boards located in the beam target area. The decoded clock and command data are then sent back to the control room optically and are compared with the original signals.

We typically exposed the opto-boards to 5 Mrad (10 hours) before moving them out of the beam-line in order to allow the VCSELs to anneal. In Figure 2 we show the PIN current thresholds for no bit errors, measured on one of the opto-boards during the irradiation study. We observe that the PIN current thresholds for no bit errors are all below 40 and remain constant up to the total dose of 32 Mrad. The optical power returned from the opto-board to the control room over the course of the irradiation for one of the opto-boards is displayed in Figure 3. We observe a general trend in the data: during an irradiation period the returned optical power decreases; as the VCSEL anneals, some of the lost power is recovered as expected. We find that power is well above the minimum spec of 350 micro-watts up to 32 Mrad.

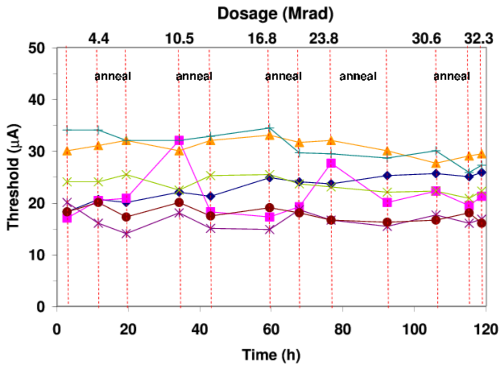

Fig. 2. Threshold for no bit errors Vs radiation dose for one opto-board in the shuttle setup.

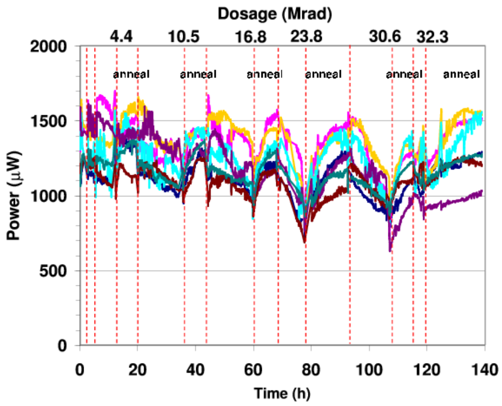

Fig. 3. Optical power Vs time (dose) for one of the four opto-boards in the shuttle setup.

4. Summary

The opto-board meet all the requirements for operation in the ATLAS pixel detector's optical readout system and further appear to be sufficiently radiation hard for ten years of operation at the LHC. We are now moving from the prototype stage of the project to the production phase.

Acknowledgments

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References

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