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Dense Optical-electrical Interface Module

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(for the CDF Collaboration)

The DOIM(Dense Optical-electrical Interface Modules) is a custom-designed optical data transmission module employed in the upgrade of Silicon Vertex Detector of CDF experiment at Fermilab. Each DOIM module consists a transmitter(TX) converting electrical differential input signals to optical outputs, a middle segment of jacketed fiber ribbon cable, and a receiver (RX) which senses the light inputs and converts them back to electrical signals. The targeted operational frequency is 53 MHz, and higher rate is achievable. This article outlines the design goals, implementation methods, production test results, and radiation hardness tests of these modules.

1. Introduction

High speed data transmission modules with compact, low-mass design and high radiation hardness are crucial components to the success of modern particle detector. The Dense Optical-electrical Interface Module (DOIM) [1], [2] is such a custom-designed readout system for the upgrade of CDF Silicon Vertex Detector (SVXII). It consists three parts - the transmitter (TX) module, the intermediate optical fiber ribbon cable, and the receiver (RX) module.

The TX module contains a 9-channel laser diode array (LDA) which converts the electrical signals to optical signals and a driver integrated circuit which conditions the input differential electrical signals [3]. Similarly, the RX module also comprises two major parts, a 9-channel photo diode array (PDA) as light sensor to convert the optical signals to electrical signals and a receiver integrated circuit to determine the states of the signals. TX is positioned inside the detector and RX is mounted on the outside acquisition system. A 22 m long commercial jacketed fiber ribbon cable (DOIM cable) with proper terminations is connected between TX and RX to guide the optical signals from the inner detector to the outside acquisition system. In CDF run2a, 560 DOIMs are used for silicon detector and additional 140 DOIMs are made as spare.

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2. Implementation of DOIM

The driver and receiver analogue ICs are implemented with the industrially available CMOS technology. The input of driver IC and the output of receiver IC are designed to be differential ECL signal. The LDA technology used for the current version TX module is the edge-emitting ridge-waveguide InGaAsP/InP quantum well lasers operating at $\lambda = 1550\ nm$. The pitch between lasers is 250 μm. For the PDA in the RX module, we use InGaAs/InP PIN photo diode arrays with pitch of 250 μm also. In each TX module, the driver IC is mounted on a thermoconductive Al_2O_3 substrate. Each channel of driver IC is bonded onto the metal trace on the substrate. The LDA is positioned on the top of the sub-mount and followed by a 100-minute baking process under 80 °C. Each TX comes with a short bare fiber ribbon (pigtail) of about two meter long, one end of the pigtail is terminated with a standard optical fiber ribbon MT connector and the other end is attached on a silicon V-groove and aligned to the emitting edge of the LDA. Home-made testing instruments with commercial large area photo sensors are used to measure the light outputs during alignment. A minimum light output of 200 μW is required for each channel. A plastic cover of 18 $mm \times 8\ mm \times 3.5\ mm$ is placed on the substrate to enclose both the driver IC and LDA for protection. This step is performed in an environment filled with N_2 gases to reduce the humidity which make the H_2O molecules condense on the laser diode surface and may destroy the light signal transmission. Each TX has to go through a burn-in process for 72 hours under 70 °C. The assembly procedure of RX is similar to TX except that the pigtail length is 23 cm and is terminated with a MTP connector. The package size of RX is 15 $mm \times 8\ mm \times 3.5\ mm$. The 22 meter long DOIM cable is terminated with MT and MTP connectors at both ends, the insertion loss is required to be < 0.5 dB per connector.

3. Production Tests

The production grade of the fully packaged TX and RX module came out in the Spring of 1999. Various tests have been performed on these modules to establish their basic operational characteristics and their survivability in radiation environment.

3.1. *TX light output power test*

TX is powered up with two separated power levels, one is Vcc, 5V, for the driver IC, the other one is Vld, 2V, for the LDA. The optical power level and waveform of each channel is converted to electrical signal by a commercial O/E converter and observed with a digital oscilloscope. During the measurement the TX is enclosed within a Al heat sink and cooled down by cooling fans or TE cooler, the operating temperatures are $30 \sim 35\ °C$ and $27 \sim 29\ °C$ respectively with these two cooling methods. In average the light output of the TXs is between $300 \sim 400\ \mu$W.

3.2. *Bit error rate test*

Bit Error Rate (BER) is the ratio of the number of bits with error to the total number of bits received. Each TX and RX has to go through the BER test. The DOIM specification requires the BER to be $< 10^{-12}$. To do the BER test, we used the Fermilab custom-designed Bit Error Rate Tester (BERT) [4]. A random pattern is generated by BERT and transmitted to TX, the pattern received by RX is then compared to the original pattern. The BER tests are running at 63 MHz, which is higher than the CDF operating frequency of 53 MHz. For each test, it takes about 5 hours to accumulate more than 10^{12} testing words, however, about 40% of the samples are tested up to 19 hours (4.3×10^{12} words) and about 10% up to 70 hours(1.5×10^{13} words). The longest run so far was running up to 90 days(4.8×10^{14} words) without error.

3.3. *TX radiation hardness test*

In CDF run2a, the TX is expected to receive an average dose of 250 kRad. At Nov. 1999 we used 10 TXs to do the the radiation test with 63 MeV proton beam at UC DAVIS for 200 kRad and 400 kRad. The consuming currents of these TXs showed no change after the radiation exposure. The light output powers were degraded to about 87+-8% and 80+-20% with the exposure of 200 kRad and 400 kRad respectively.

4. Conclusion

The 700 pairs of TX and RX had been produced already. They are successful in light output test and bit error rate test. The radiation hardness test shows that DOIMs are still working even after the exposure of 400 kRad, which is better than the specification of 250 kRad.

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References

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