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Modulator Based High Bandwidth Optical Readout for HEP detectors

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Optical links will be an integral part of future HEP experiments at various scales from coupled sensors to off-detector communication. We are investigating light modulators as an alternative to VCSELs. Light modulators are small, use less power, have high bandwidth, are reliable, have low bit error rates and are very rad-hard. We present the quality of the links at 10GB/s and the results of radiation hardness measurements for the modulators built based on LiNbO3, InP, and Si. Also we present results on free space links, steered by MEMS mirrors and optical feedback paths for the control loop.

Summary

Optical links will be an integral part of future high energy physics experiments at various scales from coupled sensors through intra-module to off-detector communication. With increasing luminosity in LHC experiments, the optical bandwidth required to transfer data from the detector to outside will increase rapidly to keep the hardware triggers low. Also the radiation hardness requirements of the hardware components used for at the detector increase with the luminosity. We are investigating light modulators as an alternative to commonly used VCSELs. Light modulators are smaller, use less power, have high bandwidth, are more reliable, have low bit error rates and are very rad-hard compared to VCSELs and appear to be more economical as well. We have constructed a test system with 3 such links, each operating at 10Gb/s. We present the quality of these links (jitter, rise and fall time, bit error rates) and eye mask margins (10GbE) for 3 different types of modulators: LiNbO3-based, InP-based, and Luxtera Si-based.
We irradiated three types of modulators at the cyclotron at Massachusetts General Hospital (MGH), which delivers protons up to about 216MeV. An FPGA-based board situated about 10m away from the beam (shielded from radiation) was used to generate four 10.325Gb/s signals with 10GBASE-R specification (IEEE802.3ae) through the optical links. Two optical links were based on Luxtera Si modulators while the other two were based on InP and LiNbO3 modulators. The FPGA was designed to compare the returned bit streams with the original stream to identify any bit errors. We irradiated the three types of modulators with four different energies: 207, 168.9, 128.6 and 84.9MeV. With all four runs combined, 7.91x10^11p/cm2 of fluence and 63.7krad of TID were received. During all four runs, no bit errors were observed with all three types of modulators. A modified Luxtera Si modulator is being considered for ATLAS Tile-Calorimeter upgrade II due to its superior signal quality and low cost.

In addition we present results on free space data links that could be used to couple light in and out of modulators by utilizing steering by MEMS-mirrors and optical feedback paths for the control loop. Instead of fibers the light beams could be steered in air into the modulators by using MEMS-mirrors and special light couplers. Since fibers are radiation sensitive, particularly in areas where there is very high rate of exposure, the free space beam suffers no consequence over the lifetime of the experiment. Also free space beams reduce the complexity of fiber routing while also reducing the latency due to velocity factors and delay drift due to thermal effects compared to fibers. There are also areas where fiber connectors are too large and too massive.

Some future developments of optical modulator-based high bandwidth optical readout systems, and applications based on both fiber and free space data links, such as local triggering and data readout and trigger-clock distribution, are also discussed.

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