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Towards Optical Data Transmission for High Energy Physics Using Silicon Photonics

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Future upgrades of CERN Experiments will require low power optical data links to support ever-increasing data-rates at ever-higher radiation levels. Silicon Photonics is a CMOS optoelectronics technology compatible with such requirements. We present the results of an optical transceiver proof of concept based on a Silicon Photonic Integrated Circuit coupled to existing radiation tolerant ASICs.

Summary (500 words)

A new generation of radiation tolerant optical links is being developed to cope with the increased data volume and radiation levels in the innermost regions of the HL-LHC.

The architecture of optical data links for particle detectors developed so far combines custom rad-tolerant optical transceivers deployed at the front-end with commercial off-the-shelf (COTS) optics and electronics deployed at the other end of the link in a radiation-free area. Optical transceivers (TRx) are bidirectional modules with the receiver (Rx) channel converting data from the optical to the electrical domain and the transmitter (Tx) channel doing the opposite (electrical to optical). The radiation tolerance of the optoelectronic technology currently used (based on VCSELs and pin photodiodes) does not allow the use of optical link components in the innermost regions of the detectors.

Within the CERN EP R&D program we are investigating the use of Silicon Photonics (SiPh) for the rad-tolerant optical transceiver that will be installed close to the readout electronics of silicon particle sensors. SiPh leverages CMOS fabrication processes to realise optical components and circuits on silicon chips. Recent studies have shown high levels of radiation tolerance of SiPh components to Total Ionizing Dose (TID) and Total Fluence.

The test vehicle used to carry out this research activity is a Photonic Integrated Circuit (PICv2) that we designed and fabricated through a multi project wafer (MPW) using the imec Silicon Photonics foundry. The chip integrates various optical components and circuits that can be used to build data transmission lab demonstrators and to study the radiation tolerance of the SiPh technology.

In this work, we present the result of a front-end transceiver demonstration that uses optical components integrated onto PICv2 together with existing rad-tolerant ASICs. The Tx is based on a micro-Ring Modulator (RM) driven by the lpGBT, a radiation tolerant SerDes developed at CERN for the HL-LHC detectors. The RM was connected to the differential CML output of the lpGBT Tx. This implementation shows a wide open 10.24 Gb/s eye diagram of the signal transmitted through the single-mode optical fiber (SMF), validating the compatibility of CML signals with driving RMs. The Rx is based on a Germanium (Ge) high-speed photodiode coupled to the GBTIA, a radiation tolerant transimpedance amplifier widely used for the front-end receiver of optical data links at CERN (the common projects Versatile Link and Versatile Link+). We demonstrated the compatibility of integrated Ge photodiodes with the existing rad-tolerant TIA that was designed to operate with discrete pin photodiodes. The receiver, when operating at 4.8 Gb/s, shows a sensitivity of approximately -10 dBm. The optical signal was fed into the receiver using standard SMF, and the use of polarization splitting grating couplers makes the receiver polarization insensitive. In synergy with the CMS development for phase-3 Inner Tracker upgrade, we plan to transmit data from RD53 Pixel Read-out Chips over optical fiber using rad-tolerant SiPh TRx for the first time.

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