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System development of Silicon Photonics links for CERN Experiments and Accelerators

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Future upgrades of the CERN Experiments and Accelerators require optical links capable of handling the large data volume generated in particle detectors and beam position (BPMs) sensors. Silicon Photonics optical transceivers are the best candidates to cope with the required data rate and radiation tolerance. We present the experimental characterization of Silicon optical modulators and Germanium photodiodes together with lab demonstration of optical transmitters and receivers based on CERN custom designed Silicon Photonics integrated circuits.

Summary (500 words)

The final Runs of the High Luminosity LHC at CERN (Run 5 and Run 6) will require data links for both the Experiments and the Accelerators that allow high data rate and have high radiation tolerance. Silicon Photonics is a CMOS technology enabling the manufacture of integrated optical circuits on Silicon chips. In recent years, significant investments have been made worldwide to consolidate the manufacturing process and establishing commercial foundries able to satisfy the needs of the fiber optic communication market. Advantages of this technology are the high bandwidth and the low power consumption of the optical components, the compact footprint of the optical circuits, and the high radiation tolerance. These aspects enable the design of compact optical transceivers in chiplet format with high data rate and high radiation resistance that could be deployed in any region inside particle detectors, overcoming the impairments represented by low mass copper cables currently deployed in the innermost areas of the CERN Experiments.

Within the Work Package 6 of the CERN EP R&D project, we are tackling the system aspects of optical links based on Silicon Photonics circuits. The test vehicle for this development is a Silicon Photonics Integrated Circuit (PICv2) that was designed at CERN and manufactured by imec as a part of a multi-project wafer (MPW) run using the iSiPP50G platform. PICv2 includes components like modulators, photodiodes, waveguides, and fiber couplers organized in circuits that enable optical data transmission demonstrations.

High Energy Physics applications require asymmetric optical links with high data rate (» 10 Gb/s) in the uplink (from the sensor to the back-end readout electronics) and lower data rate (< 5 Gb/s) in the other direction, the downlink. On the uplink side, we present data transmission experiments of Silicon ring modulators connected to commercial drivers and custom ASICs. Ring modulators are the core building blocks of the optical link. We show the operating principle reproduced in simulation and the experimental characterization of the high-speed operation up to 25 Gb/s Non-Return-to-Zero (NRZ), and 25 Gbaud Pulse Amplitude Modulation 4-level (PAM4). Moreover, we show the specific requirements in terms of biasing conditions and wavelength tuning of this modulator type. Ring modulators enable the implementation of wavelength division multiplexing (WDM) schemes, where N channels are multiplexed into the same fiber modulating N laser sources at different wavelengths. The first demo of a 4 channel WDM transmitter based on an optical circuit implemented onto PICv2 will be discussed. On the downlink side, we present the experimental results of receivers based on Germanium photodiodes integrated onto PICv2 coupled to custom rad tolerant transimpedance amplifiers, GBTIA and lpGBTIA.

Primary authors: SCARCELLA, Carmelo (CERN); DETRAZ, Stephane (CERN); LALOVIC, Milana (University of Belgrade (RS)); MARCON, Leonardo (CERN); OLANTERA, Lauri (CERN); PROUSALIDI, Thenia (National Technical Univ. of Athens (GR)); SANDVEN, Ulrik (CERN); SIGAUD, Christophe (CERN); SOOS, Csaba (CERN); TROSKA, Jan (CERN)

Presenter: SCARCELLA, Carmelo (CERN)

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