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Optical Link for Detector Instrumentation: In-Detector Multi-Wavelength Silicon Photonic Transmitter

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We report on our recent progress in developing an optical transmission system based on wavelength division multiplexing (WDM) to enhance the read-out data rate of future particle detectors. The design and experimental results of the prototype of a monolithically integrated multi-wavelength transmitter are presented as well as temperature studies of electro-optic modulators and optical (de-)multiplexers. Furthermore, we show the successful permanent coupling of optical fibers to photonic chips, which is an essential step towards packaging of the opto-electronic components.

Summary

The ever-increasing number of electronic channels in detector instrumentation results in a keen demand on high data read-out capacity. An optical data transmission system based on wavelength division multiplexing (WDM) will provide a generous data rate up to the Tbit/s range.

In state-of-the art solutions, individual optical fibers connect directly modulated laser diodes to a corresponding receiver in the periphery of the detector. Recently, we proposed a WDM-based optical transmission system [1], where a single optical fiber carries numerous optical channels. This increases the data read-out capacity significantly while reducing the number of individual fibers connecting read-out chips with the data acquisition units. Furthermore, the laser sources providing the optical carriers are located off-detector and thus do not contribute to the energy budget within the detector volume.

The essential building block is the monolithically integrated transmitter on a silicon-on-insulator (SOI) substrate. An optical demultiplexer separates incident optical channels in order to forward each of them to a Mach-Zehnder modulator, which encodes information on the respective carrier. A multiplexer merges all data-carrying signals to be transported over a single optical fiber. The (de-)multiplexers are implemented as planar concave gratings (PCG), where the channel separation or merging is achieved by means of diffraction. The optical modulators are implemented by Mach-Zehnder interferometers consisting of two identical phase shifters.

We present the design and experimental results of a prototype of an integrated optical 4-channel transmitter with demultiplexer, modulators and multiplexer as well as a study on the influence of temperature on the individual components. As expected, the PCG filter characteristic is shifting with varying temperature over a range of 70 K. No other change in behavior is observed. Similar studies are performed on depletion-type pn-modulators. The variation of the temperature induces a constant offset of the operating point but does not affect the modulation efficiency.

To bring a photonic integrated circuit (PIC) to operation, packaging and a permanent coupling of optical fibers is required. Due to the tight positioning tolerances, a sub-micrometer precision alignment and bonding is necessary. We show recent progress of our activities in establishing a fiber coupling process, where the optical fibers are attached to the PIC by means of UV-curing adhesives. This coupling arrangement does not impose additional insertion loss compared to a continuously controlled fiber alignment in the laboratory. It appears to be permanently stable based on observing the coupling efficiency over more than a month.

Reference

[1] P. Skwierawski et al. 2016 *JINST* **11** C01045

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