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Concept, design and verification of components for an integrated on-detector silicon photonic multi-channel transmitter unit

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We report on the latest developments of a silicon photonic optical transmission system based on wavelength division multiplexing (WDM) for high-speed links in detector instrumentation. The essential component is a monolithically integrated multi-wavelength transmitter based on depletion-type pn-modulators. Based on our designs, a photonic transmitter chip has been fabricated. We present experimental results of its components such as modulators, (de-)multiplexers and power couplers and discuss the development process starting from the concept and the component design through to simulations and experimental results. With this chip, all building blocks are available for building a link demonstrator.

Summary

With continuously refining energy and time resolutions of modern detector systems, the number of electronic read-out channels increases significantly. While massive parallelization in electronic pre- and post-processing provides the appropriate processing speed, the data link between the detector's front-end electronics and the counting room progressively becomes the bottleneck of the entire system.

State-of-the-art read-out infrastructures rely on optical links using directly modulated laser diodes as on-detector transmitter units. Each transmitter is connected to an off-detector receiver by a single optical fiber. To reduce the total number of fibers between the detector and the counting room, we have proposed an optical transmission system based on wavelength-division multiplexing (WDM) [1], where numerous optical channels are transported over a single optical fiber. Apart from reducing the number of physical links, the system potentially reduces the on-detector power budget significantly. This is accomplished by placing the laser sources providing the optical carriers off the detector volume.

The essential element of the transmission system is the monolithically integrated WDM transmitter on a silicon-on-insulator (SOI) substrate. The operation principle is as follows: a demultiplexer separates the incident optical channels by their wavelength. Each of them is forwarded to an electro-optic modulator, which encodes data on the respective carrier. For transporting all signals back to the counting room over a single fiber, they are merged by an optical multiplexer. The electro-optic modulators are implemented by Mach-Zehnder interferometers with a depletion-type pn phase shifter in each arm. The planar concave gratings (PCG) (de-)multiplexers rely on channel separation or merging by means of diffraction.

Based on our designs, a photonic chip has been fabricated. Alongside two variants of an integrated 4-channel transmitter consisting of a demultiplexer, modulators and a multiplexer, the chip contains numerous active and passive components for characterization purposes. Among others, those are a thermal modulators for operating point adjustment, (de-)multiplexers and power couplers.

In this work, we show the concept and design of essential photonic components including the development of efficient simulation methods. Experimental results of selected active and passive components are presented. The voltage-length product of the depletion-type pn-modulators is 6 V·cm. The thermal modulators achieve a full π-phase shift at a length of 100 µm at a heating power of 28 mW. The average channel loss of the optical (de-)multiplexers is below 4 dB and the cross talk is less than -20 dB. With this photonic chip, we have all building blocks for the integrated transmitter available to construct a link system demonstrator.

Reference

[1] D. Karnick et al 2017 JINST 12 C03078

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