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Silicon photonic components on the COTTONTAIL chip

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We report characterization results for our new silicon photonic chip for high-speed data transmission, called COTTONTAIL (Chip for detector instrumentation with wavelength division multiplex). Modulation bandwidths of different conventional and radiation-hardened travelling-wave Mach-Zehnder modulators are sufficient for very high data transmission rates. Wavelength filters for wavelength division multiplexing show a very low transmission loss of less than 2 dB with a slight wavelength shift of the filtering characteristics. Also included photodiodes are well suited for high speed downlinks in excess of 40 Gbps or on-chip modulator monitoring.

Summary (500 words)

Novel optical links using wavelength division multiplexing (WDM) will handle the increasing data transmission bandwidth requirements and reduce the fiber count in future detectors.

Our newest silicon photonic chip (figure a)) was delivered in December 2023 and is now being characterized. We made measurements on conventional and radiation hardened, travelling wave Mach-Zehnder modulators (MZM) of different lengths. Their DC-characteristics shows a very low V_{pi;}L of less than 2 Vcm per modulator arm. As the MZMs offer an inherent push-pull-control for RF driving, this value is halved to less than 1 Vcm in a final system. RF characterizations show an efficiency drop for frequencies up to 7 GHz and then a long plateau up to around 30 GHz (figure b)). Efficiency slowly drops again for even higher frequencies. This leads to the odd phenomenon that higher link speeds should transmit better than lower link speeds, if the same line coding is used. At the time of writing this abstract, we still investigate this behavior to attribute it to the device or the setup. Currently we prepare data transmission experiments as well as the characterization of an MZM with integrated biasing network to save space and of segmented MZMs with phase shifters of different lengths to achieve PAM4 data transmission without the need of a DAC.

Furthermore, thermal modulators are included for working point control of the fast pn-MZMs. A 100 µm long phase shifter requires just 35 mW of heating power for a pi;-shift, which is very efficient. These thermal phase shifters are included in all MZM-WDM-systems and most of the single MZMs on the chip.

Four different types of germanium photo diodes (PD) with different properties are included in the chip. Their characteristics were measured using optical beat frequency generation. Even the slowest PD, labeled as monitor diode, achieves a 3dB-cut-off frequency of more than 22 GHz, while the others, medium to very high-speed diodes, show 3dB-cut-off frequencies up to 33 GHz, likely limited through the connector layout and electrical impedance mismatch. They are well suitable for high-speed downlink channels or modulator monitoring.

The included optical (de-)multiplexers used for the WDM systems show a very low insertion loss of only 1.9 dB and a channel-to-channel crosstalk of less than -25 dB. Filter characteristics is shifted from the designed wavelengths by 1.7 nm to shorter wavelengths. Simulations show that this can be caused by a 1.1 nm thinner silicon layer than expected and is easily explained by the thickness tolerances of the used SOI wafers.

In total, four 4-channel WDM-systems are integrated in the chip. Two are using four ring modulators in a row, two use 3 mm long MZMs with integrated thermal phase shifters for working point control and optical (de-)multiplexers. Of the latter, one system uses standard, one radiation hardened components. Due to the complex electrical contacting, characterization of the whole WDM-systems is postponed to the second half of this year and we are confident to present results at the conference.

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