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Photonic integrated transceivers for data read-out systems

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Abstract: In this work design and characterization results of integrated optical transceivers are presented. The devices were realized as photonic integrated circuits in a generic InP-based technology. The application is a data read-out unit for a sensor network. The circuits utilize PIN photodiodes for detection of a slow speed signal and amplitude modulators, either in a Michelson or a Mach-Zehnder interferometer configuration, for data encoding. Modulation bandwidth of 16.1 GHz was measured, eye-diagrams with 11.6 dB dynamic extinction ratio were recorded and transmission of a 10 Gb/s signal over 25 km of SMF fiber with BER below 10^{-10} was achieved.

Introduction

In a distributed sensor network, the read-out system is responsible for collecting all signals generated by a large number of sensors. The system we consider here has a star topology and comprises microelectronic and optoelectronic devices located next to the sensors, and is connected with optical fibers to a central station (CS). The upstream signal, towards the CS, provides information about the monitored physical parameters, while the downstream from the CS may be used for sending a control signal to the sensor units. Figure 1 presents a scheme of an optical link between the central station and a single sensor, where the downstream is a 1.25 Gb/s digital signal, modulated with low extinction ratio (ER = 0.4 dB). At the sensor unit a fraction of the input power is tapped and the downstream signal is detected. The remaining signal is used as a carrier for modulation with high extinction ratio in order to generate the upstream signal. It is assumed that the read-out from the sensor as well as driving the modulators is performed by electronic circuitry deployed at the sensor unit.

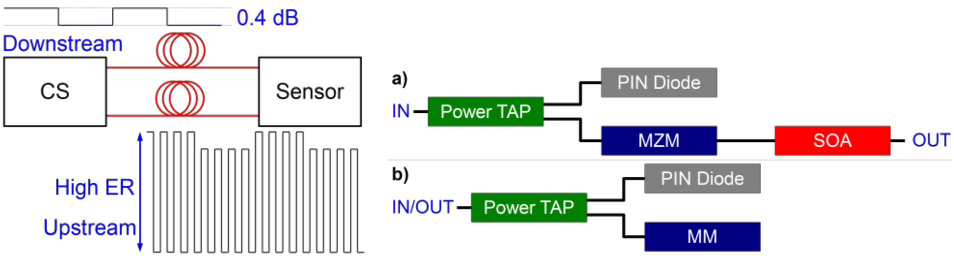

Fig. 1. Optical fiber link between the central station (CS) and a single sensor (left) transceiver circuit schemes in transmitting (a) and reflecting (b) configurations (right)

This concept, based on discrete photonic components, has been proposed and investigated by the Dutch institute for subatomic physics (Nikhef) for the data read-out system of the KM3NeT neutrino telescope experiment[1]. It utilized a 5%:95% fiber-optic power coupler, a PIN photodiode and a reflective electro-absorption modulator. In this work we demonstrate photonic integrated circuits that combine all of the functionality in a single semiconductor chip. We utilized an InP-based generic integration technology platform[2]. It supports building blocks such as passive waveguides, electro-optic phase modulators exploiting the quantum confined Stark effect[3], PIN photodiodes and semiconductor optical amplifiers.

Chip design

Figure 1 presents the block diagrams of the designed circuits. Two possible arrangements are presented. Both of them utilize a power tap, which is either a symmetric 50%:50% 1x2 MMI power splitter or a 15%:85% 2x2 MMI power coupler, and a PIN photodiode for monitoring the downstream signal. The data from the sensor is encoded onto the carrier using amplitude modulators in either transmissive Mach-Zehnder (MZM) or reflective Michelson (MM) configuration, constructed from MMI couplers and phase modulators. Additionally, the transmitting circuits utilize a semiconductor optical amplifier in order to boost the power of the output signal. Figure 2 presents the mask layout of the transmitting circuits with two additional test circuits and a picture of a fabricated device mounted on a ceramic block for RF characterization. The chip dimensions are 6x2 mm^2.

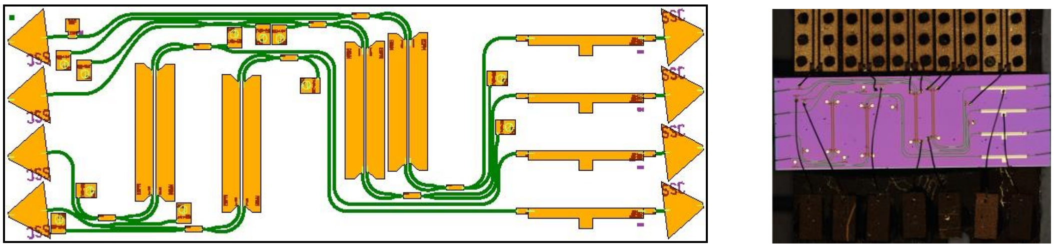

Fig. 2. Mask layout of the transceiver circuits in a transmitting configuration (left) and microscope photograph of the chip mounted for RF-characterization (right)

Characterization results

For the RF measurements the chips were mounted on ceramic submounts and the circuit components were wire-bonded to the gold DC pads and RF ground-signal-ground (G-S-G) coplanar transmission lines. The RF-response of the modulators was measured with a 67 GHz lightwave component analyzer (LCA, Agilent N4373C) by injecting CW laser light at 1550 nm and analyzing the modulated signal by the LCA. Figure 3 presents the characteristics of the S_{21} magnitude, normalized at 0 GHz, for the Mach-Zehnder and Michelson type modulators. The measured 3 dB bandwidth is 11.5 GHz and 16.1 GHz, respectively.

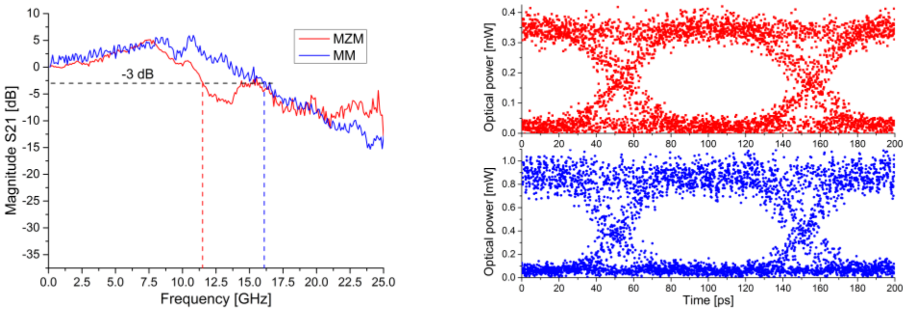

Fig. 3. Frequency response (left) and eye diagrams for an NRZ 10 Gb/s signal (right)

The measured static extinction ratio of the Mach-Zehnder modulators is 18 dB at λ = 1550 nm and the driving voltage V_π = -3.9 V. For the Michelson arrangement the ER is 25 dB and V_π = -3.0 V. Dynamic measurements were performed with the injected CW carrier at λ = 1550 nm and a pseudo random bit sequence generator which was driving the modulators. The recorded eye-diagrams for the back-to-back configuration are presented in Figure 3 for both types of modulators. In both cases the eye is wide open with the dynamic extinction ratio 11.6 dB and 11.2 dB, respectively. For the Mach-Zehnder circuits transmission of the modulated signal for back-to-back and over 25 km of SMF fiber was achieved with a bit error rate smaller than 10^{-10} (measured with Anritsu MP1764C error detector).

Conclusions

The integrated optical transceivers were designed and fabricated in a standardized generic InP technology. Their overall performance is good in terms of dynamic extinction ratio higher than 10 dB and available RF bandwidth up to 16 GHz.

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