Optimized 20 Gbps DPSK demodulator in 220nm SOI

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***Abstract*—We present an optimized 20G-DPSK receiver fabricated in 220nm SOI technology using an unbalanced Mach-Zehnder interferometer in sequence with a Mach-Zehnder delay interferometer. Error-free operation was demonstrated for Duobinary(DB) and Alternating Mark Inversion(AMI) demodulated signals.**

Keywords-Demodulation, differential phase-shift keying (DPSK), silicon-on-insulator (SOI).

I. INTRODUCTION

While PSK requires active coherent detection using a LO, the beauty of DPSK is that it can be directly demodulated using a passive delay-interferometer; Two adjacent bits are superposed and the superposed signal is photo detected. This makes direct photo detection possible, after the demodulator circuit.

Silicon On Insulator (SOI) photonics is an interesting technology for implementing DPSK modulation format [1]. The small bending radius of about 5 microns of the integrated SOI waveguide will allow a very small footprint of the delay-interferometer specifically for lower symbol-rates since the length of the delay line is on the order of cm.

II. DESIGN AND FABRICATION

In order to convert the information in the differential phase change and to recover the binary information a demodulation circuit is implemented using a Mach-Zehnder delay interferometer (MZDI) [2] where one bit is delayed in one arm and then superposed with its adjacent bit at the output.

The proposed structure is depicted in Figure 1 including a MZI switch in series with the 20Gbps MZDI demodulator. The unbalanced MZI works as a switch and by either tuning the wavelength or by heating one of the arms using an integrated micro heater, we can control the input power to the MZDI to reduce the power unbalance between arms of the MZI due to propagation losses and hence, the sensitivity of the receiver can be actively maximized.

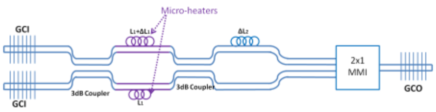

Figure 1: Block Diagram of the proposed DPSK demodulator

Figure 2 shows the simulated spectral response of the whole structure using the transfer matrix method [3]. In the simulation the 1-bit DL was set to fit a 20Gbps symbol rate, the path difference for the MZI switch to 50um and a waveguide propagation loss of 10dB per cm. To reflect the behavior of the MZI switch, the figure includes the input power to each arm of the MZDI, where the green curve is the power penalty at the input of the delay-line arm of the MZDI and the red curve for the opposite arm. It is interesting to note that when the switch is at its extreme (0:1 or 1:0) there is no resonances as expected, and the different total losses correspond to the different losses in the two arms of the MZDI.

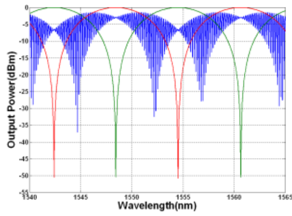

Figure 2 Simulated spectral response at the MZDI inputs (green, red) and at the demodulator output (blue).

The structure was fabricated on SOI wafer with silicon core thickness of 220 nm and buried oxide (BOX) of 2 µm, and covered by a 1µm-thick silica overcladding. The fabrication process was carried out by using electron beam lithography (EBL) and dry etching by using inductively coupled plasma (ICP) system. Plasma enhanced chemical vapor deposition (PECVD) was also used, to grow the overcladding silica layer. The figure below shows scanning electron microscope (SEM) images of the fabricated structure before metal deposition.

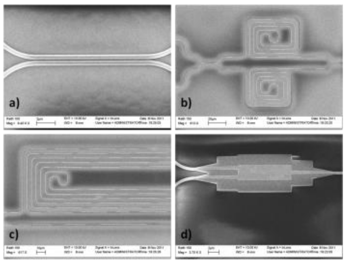

Figure 3: SEM images of a) 3dB Coupler, b) MZI with ΔL1=50µm, c) MZDI, d) 2x1 MMI

III. EXPERIMENTAL RESULTS

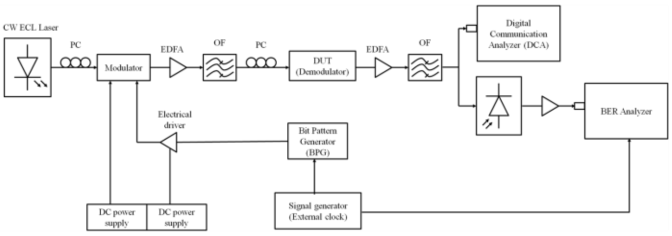

Figure 4: Block diagram of the experimental DPSK demodulation setup

Figure 4 shows the experimental DPSK demodulation setup. Continuous-wave light was generated by an External Cavity Laser (ECL) and was first spanned over the full operational wavelength bandwidth, from 1545nm to 1565nm. Figure 5 shows the obtained experimental spectrum including the optimized performances at 1548.4nm. The optical data stream was generated using a X-cut Lithium Niobate modulator, with the bits generated from a pseudorandom binary sequence pattern generator (PRBS) with a pattern length of 231-1 at 20-Gb/s bit-rate, delivered by a bit pattern generator (SHF BPG 44E) connected to an external clock. The modulated signal is then amplified by an erbium-doped fiber amplifier (EDFA), filtered by 1nm BPF and fiber coupled in and out of our device. The demodulated signal was amplified and filtered again, before being photo-detected by a Digital Communication Analyzer (Infinium DCA-J 86100C), and simultaneously examined on a Bit-Error-Rate Analyzer (SHF EA 44).

The measured spectral response of the 20Gb/s-DPSK demodulator is depicted in Fig 5.

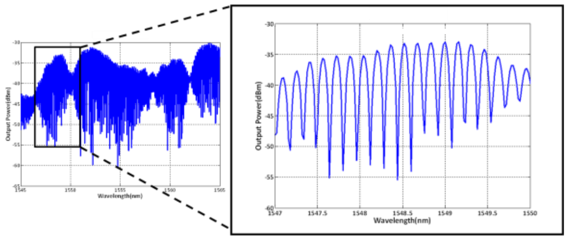

Figure 5: Measured spectral response at the DPSK demodulator. Inset: zoom in resonance of interest.

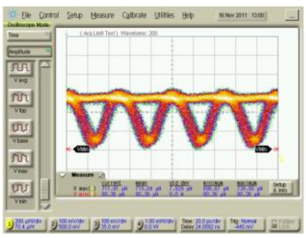

Figure 6: Eye diagram of the 20Gb/s-NRZ-DPSK input signal

Figure 6 shows the eye diagram of the 20Gb/s-NRZ-DPSK input signal while figure 7 shows the obtained eye diagrams of the demodulated AMI (7.a) and DB (7.b) signals.

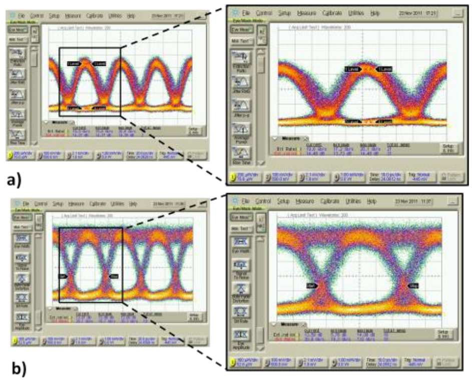

Figure 7: Eye diagram of the 20Gb/s-NRZ-DPSK for a) AMI and b) DB demodulated signals.

The measured extinction ratios, at a bit rate of 20Gb/s, are 14.7dB and 13.59 dB for AMI and DB demodulated signals, respectively. Error-free operation was achieved, and the measured bit-error-rate curves are plotted below.

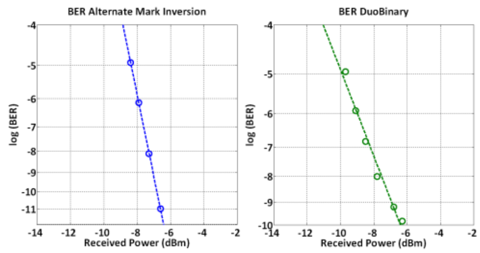

Figure 8: BER curves for based DPSK demodulation at 20 Gb/s operation for a) AMI and b) DB demodulated signals.

IV. CONCLUSION

We demonstrated an optimized design for 20G-DPSK receiver based on a 220 nm SOI unbalanced MZI in series with MZDI. Measured ERs are 14.7dB and 13.59 dB for AMI and DB demodulated signals, respectively and error-free operation was achieved. In the future, active performance will be carried out by heating one of the arms using an integrated micro heater.

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