Performance of 80 Gb/s MMI-Based DQPSK Demodulator on SOI

N. Sotiropoulos, H. de Waardt, A.M.J. Koonen
Dept. of Electrical Engineering
Eindhoven University of Technology
Eindhoven, Netherlands
n.sotiropoulos@tue.nl

D. Vermeulen, G. Roelkens
Dept. of Information Technology (INTEC)
Ghent University-IMEC
Gent, Belgium

R. Halir, G. Wangüemert-Pérez
Departamento Ingeniería de Comunicaciones, ETSI Telecomunicación
Universidad de Málaga
Malaga, Spain

***Abstract*—A Silicon-on-Insulator (SOI) Differential Quadrature Phase Shift Keying (DQPSK) demodulator based on a novel Multimode Interference (MMI) design is characterized for a number of operating wavelengths, with results indicating good uniformity and low wavelength dependency.**

Keywords- silicon integrated devices; DQPSK demodulator; MMI; characterization

I. INTRODUCTION

The introduction of multilevel modulation formats in optical communication systems has allowed the efficient scaling of system bit rates, without requiring electronics and photonics operating at very high bandwidths. Of special interest is Differential Quadrature Phase Shift Keying (DQPSK) modulation, which encodes two bits in the phase difference between two consecutive symbols, as it can be very robust against Chromatic Dispersion (CD) and non-linearities [1]. For the demodulation of DQSPK signals, a delay line equal to the symbol duration and phase shifters are required, which means that fiber-based receivers are bulky. On that respect, photonic integration can offer substantial improvement, leading to smaller, more stable and potentially low-cost receivers.

Silicon-based integration platforms are especially suitable for such applications, since they exhibit low losses and photodiodes can be easily accommodated, through hybrid or heterogeneous integration. For that reason, a number of silicon-based demodulators have already been presented [2-4]. The device characterized in this paper uses a MMI design based on a combination of shallowly and deeply etched regions, which results in very low phase errors and maintains compact design [5]. The Continuous Wave (CW) measurements of this 90^0 hybrid have been undertaken and results confirm the very good phase properties of the MMI coupler [5]. In this paper, the integrated demodulator was evaluated in a 40 Gb/s DPSK test bed, in order to determine the system performance of the device.

The work presented in this paper was funded by the Netherlands Ministry of Economical Affairs and the Netherlands Ministry of Eduacation, Culture and Science under Project MEMPHIS and by the Andalusian Ministry of Science, Innovation and Industry under Excellence Research Project P07-TIC-02946

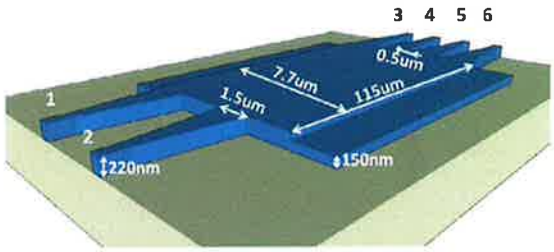

Figure 1 Schematic of the 2x4 MMI

II. DEVICE DESIGN

The device consists of grating couplers for fiber-to-chip coupling, a splitter, a 25 ps delay line (40 GHz Free Spectral Range) and the 90^0 hybrid, implemented in SOI technology. The hybrid is the most critical structure of the design and is based on a 2x4 MMI coupler. The schematic of the MMI is shown in Fig. 1, with the inputs (1 and 2) and outputs (3, 4, 5 and 6) of the structure labeled. The novelty of the MMI is the direct coupling of a shallowly etched multimode region to deeply etched waveguides. The shallowly etched region reduces the index contrast, keeping the phase errors very low. On the other hand, the rest of the waveguides are deeply etched, allowing for small curvature radii. With this approach, good imaging quality and a small footprint for the 90^0 hybrid are achieved.

III. EXPERIMENTAL SET-UP AND RESULTS

The experimental set-up built to test the device is shown in Fig. 2. The demodulator is capable of decoding DQPSK signals at 80 Gb/s, however, the DQPSK transmitter available was limited to 56 Gb/s. For that reason, the device was tested with a binary DPSK signal at 40 Gb/s. A tunable laser source creates the CW signal which enters, after polarization control, the DPSK transmitter subsystem, where it is modulated in order to create the 40 Gb/s Non-Return to Zero (NRZ) DPSK signal.

The output power of the transmitter is fixed at -3 dBm. Then, the signal is inserted to a variable optical attenuator (VOA), where the received power is set. Afterwards, the attenuated signal passes through two amplification stages (EDFAs) and is launched into the chip with a fixed power of +17 dBm. High input power was necessary, in order to compensate for the coupling and on-chip losses, which were around 20-23 dB (approximately 6.5 dB from each of the grating coupler, 6.5 dB insertion loss from the MMI and 1 dB propagation losses). The demodulated signal is coupled out of the device and is amplified by an EDFA to +7 dBm and filtered (to remove the excess ASE noise). The demodulated signal is detected by a balanced photo-detector pair, which lacks an integrated Trans-Impedance Amplifier (TIA). The lack of electrical post-amplification meant that optical amplification after the chip had to be employed, to ensure that the detected electrical signal had a voltage level above the sensitivity of the Error Analyzer (EA).

To verify the performance of the device, BER measurements as a function of the received power for every output of the device, with single-ended detection, for a number of wavelengths were performed. The BER curves for the 1535 and 1550 nm are shown in Figs. 3a-b, obtained using a pattern length of 2^{31}-1 in the experiments. From the results it can be seen that there is good uniformity between all the outputs of the device. As far as wavelength dependency is concerned, optimal performance is observed for the 1535-1550 nm range, with a small penalty for higher wavelengths (not shown here). This is in agreement with the CW measurements, which indicated optimum performance up to a wavelength of 1560 nm [5]. After validating every individual 90^0 hybrid output, experiments involving balanced detection of a pair of outputs were performed. Due to the fact that both outputs needed to be amplified and that the pulse length is quite short, there was a misalignment between the two bit streams that had to be corrected by inserting fiber patch cords and tunable optical delays. That approach required a short pattern length, 2^7-1, to enable the aligning of the bit stream through a scope. The results of balanced detection for outputs 3 and 6 for a number of wavelengths can be seen in Fig. 4. An improvement over the single-ended case, as expected, can be clearly seen. A small wavelength dependency, around 1 dB, can also be observed.

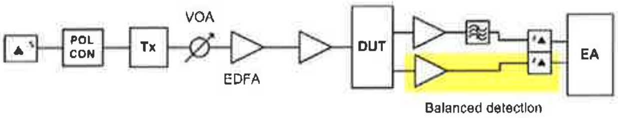

Figure 2 Experimental set-up

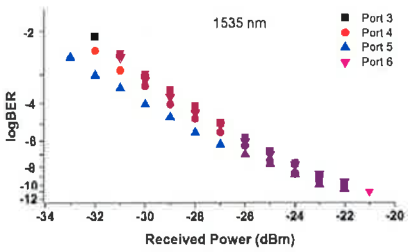

Figure 3a BER vs. received power, λ=1535 nm

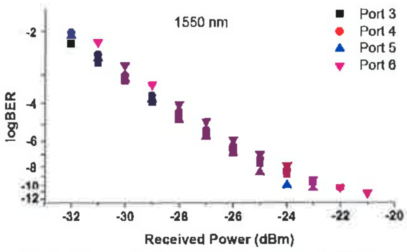

Figure 3b BER vs. received power, λ =1550 nm

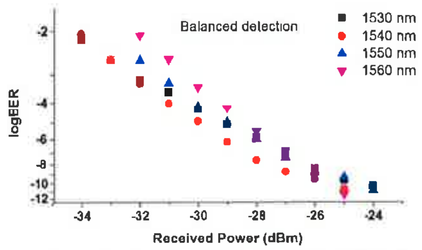

Figure 4 BER vs. received power, balanced detection

IV. CONCLUSIONS

The system performance of a MMI-based SOI DQPSK demodulator was validated at 40 Gb/s in this paper. The results prove the very good phase error properties of the novel MMI design and demonstrate low wavelength dependency. Combined with integrated photo-detectors, very high-speed, compact and potentially low-cost integrated receivers for advanced modulation formats can be realized.

REFERENCES

[1] D. van den Borne, S.L. Jansen, E. Gottwald, P.M. Krummrich, G.D. Khoe, and H. de Waardt, "1.6-b/s/Hz Spectrally efficient transmission over 1700 km of SSMF using 40 × 85.6-Gb/s POLMUX-RZ-DQPSK," J. of Lightw. Tech., vol.25, no.1, pp.222-232, Jan., 2007

[2] K. Voigt et al., "Performance of 40-Gb/s DPSK demodulator in SOI-technology," IEEE Phot. Tech. Lett., vol.20, no.8, pp.614-616, Apr. 15, 2008.

[3] Y. Sakamaki et al., "One-chip integrated polarisation-multiplexed DQPSK demodulator using silica-based planar lightwave circuit technology," Electr. Lett. , vol.46, no.16, pp.1152-1154, Aug. 5, 2010.

[4] C.R. Doerr, L. Chen , "Monolithic PDM-DQPSK receiver in silicon," 36th European Conf. on Optical Comm. (ECOC), 19-23 Sept., 2010.

[5] R. Halir, G. Roelkens, A. Ortega-Moñux, and J. G. Wangüemert-Pérez, "High-performance 90° hybrid based on a silicon-on-insulator multimode interference coupler," Opt. Lett., vol. 36, no. 2, p.p. 178-180, Jan. 15, 2011.

Thursday, 19 April 2012 / Hall-Auditorium. Poster 2. 15:30h – 17:00h

- ***Design and optical response of a thin film structure enhancing the photoluminescence of an embedded single layer of Er3+ ions (ID 85)***

This paper presents a thin film structure designed for optimizing the excitation efficiency of a single layer of luminescent Er3+ ions embedded in a solid host medium. In this structure, the Er3+ ions are located on top of a single layer of amorphous Si nanoparticles acting as sensitizers for the rare-earth excitation. This a-Si/Er active layer is sandwiched between two amorphous Al2O3 thin layers, the thickness of which is chosen so that the excitation electric field is maximized at the Si nanoparticles. Optical characterization of a thin film with such a structure grown by pulsed laser deposition shows the presence of a bandgap absorption (due to electron confinement in nanostructures a few nm in size), measurable Er3+ photoluminescence (in contrast with a single layer of Er3+ ions embedded in amorphous Al2O3) and evidence of a sensitization mechanism involving the Si nanostructures.

J.Toudert; J.Martin Sánchez; R.Serna

- ***Angularly robust resonant reflection from corrugated slab waveguide by mode coalescence (ID 49)***

Mode coalescence in a double-sided corrugated high-index dual-mode slab waveguide suppresses the spectral splitting of the normal incidence resonant reflection peak upon an angular offset. The resulting angular robustness enables this polarization- and wavelength-selective reflection effect to be used to optically process free-space light beams emitted by low coherence sources.

O.Parriaux; Y.Jourlin; S.Tonchev; A.Tishchenko; F.Lacour

- ***Performance of 80 Gb/s MMI-Based DQPSK Demodulator on SOI (ID 53)***

A Silicon-on-Insulator (SOI) Differential Quadrature Phase Shift Keying (DQPSK) demodulator based on a novel Multimode Interference (MMI) design is characterized for a number of operating wavelengths, with results indicating good uniformity and low wavelength dependency.

N.Sotiropoulos; H.de Waardt; A.M.J.Koonen; D.Vermeulen; G.Roelkens; R.Halir; G.Wangüemert-Pérez

- ***Optimized 20 Gbps DPSK demodulator in 220nm SOI (ID 73)***

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.

M.Aamer; A.Hakansson; A.Brimont; A.M.Gutierrez; A.Griol; P. Sanchís

ECIO 2012 APRIL 18-20 SITGES.BARCELONA.SPAIN

16th european conference on integrated optics and technical exhibition

Organized in conjunction with:

OWTNM 2012

International Workshop on Optical Waveguide Theory and Numerical Modelling.
April 20-21.

FIB for Photonics 2012

International Workshop on Focussed Ion Beam Technology.
April 17.