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4-Channel All-Optical Mode Demultiplexing on a Silicon Photonic Chip

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Mode-division multiplexing (MDM) is a promising approach to boost the capacity of optical fibers [1]. Yet coherent detection and power hungry multiple-input multiple-output (MIMO) digital signal processing (DSP) are typically required to unscramble mixed modes. Here, we demonstrate a 4-channel silicon photonic MIMO demultiplexer performing all-optical unscrambling of four mixed modes using a mesh of cascaded Mach-Zehnder interferometers (MZIs). Demultiplexing of 10 Gbit/s channels with less than -20 dB crosstalk and with a power penalty of 1.5 dB at BER level of 10^{-8} is achieved.

Figure 1(a) shows a schematic of the 4-channel all-optical MIMO demultiplexer, according to the architecture proposed in [2] and designed with commercial circuit simulator ASPIC [3]. Four optical channels (Ch. A – Ch. D) are mixed on-chip through a multimode waveguide section (thus emulating a low-dispersion fiber) and then coupled into four single-mode optical waveguides. The all-optical MIMO demultiplexer consists of an arrangement of 6 integrated MZIs, that can be sequentially tuned to arbitrarily extract each channel at each output port (OUT1–OUT4). Transparent detectors [4] are employed to monitor the switching state of each MZI without impair mode orthogonality. A top-view photograph of the Si chip is shown in Fig. 1(b); the SiP demultiplexer was realized using buried channels Si waveguides on a 220nm SOI platform realized through LETI-ePIXfab multi-project-wafer run. Two thermal actuators are integrated in each switching stage to control the relative phase of the

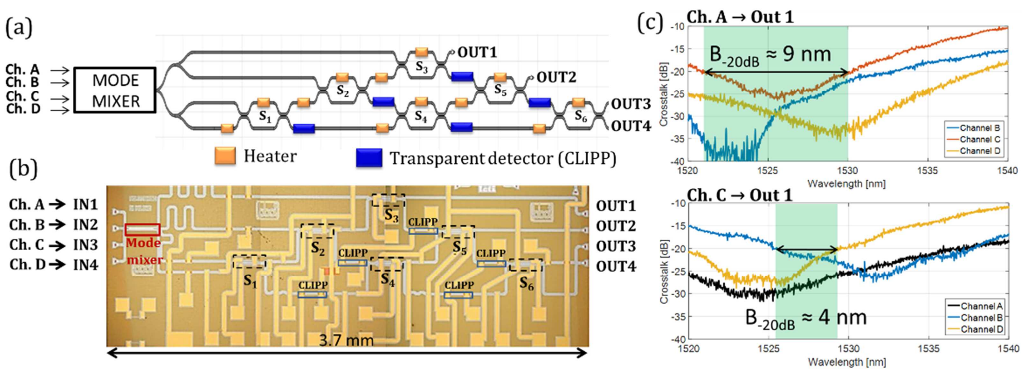

Fig. 24: (a) Scheme and (b) photo of the MDM demultiplexer. Switching stages (S_1...S_6) and CLIPP detectors are highlighted. (c) Crosstalk spectra for two extracted channels (Ch.1 and Ch. 4) at port OUT1; bandwidths with a crosstalk of -20dB are highlighted.

optical field at the input ports and between the inner arms of each MZI. Fig.1 (c) shows the channel crosstalk spectra when the demultiplexer is configured to extract Ch. A (top panel) and Ch. C (bottom panel) at output port OUT 1. A crosstalk lower than -20dB can be obtained across bandwidths spanning over several nanometers.

To evaluate system performance of the MIMO demultiplexer, we simultaneously injected four 10 Gbit/s signals (on-off keying, 2^{31}-1 PRBS, carrier wavelength 1528 nm) at all the input ports (IN1-IN4), and we tuned the circuit to sequentially extract every channel from OUT 1. Figure 2 shows bit-error-rate (BER) and eye diagram measurements of the demultiplexed channels in the cases considered in Fig. 1 (Ch. A and Ch. C), both in presence and absence of the other interfering channels. Despite a slight signal quality degradation due to -20 dB residual crosstalk, a good eye-opening is preserved. As shown in the BER measurements, power penalty compared to the reference performance (blue curves, interfering channels OFF) is about 1.5 dB (red curves, three interfering channels ON) at a BER level of 10^{-8} for both Ch. A and Ch. C. Similar performances were observed when extracting the other two channels, Ch. B and

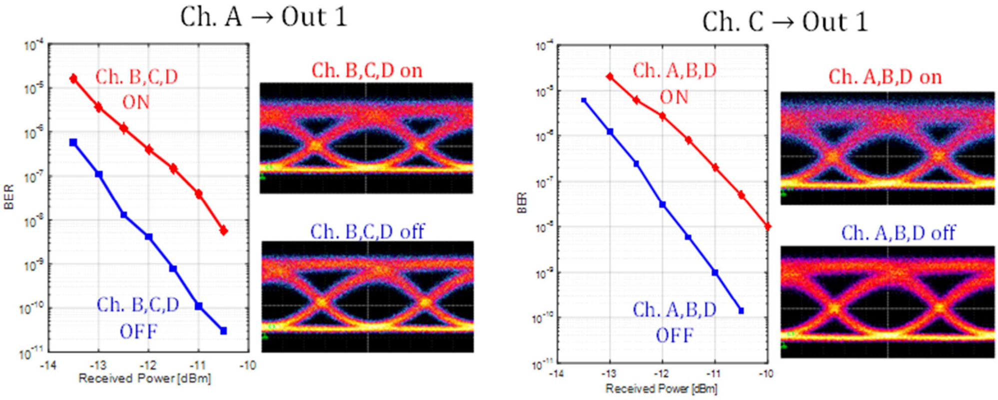

Fig. 2: BER measurements and eye diagrams for Ch. A (left panels) and for Ch. C (right panels) when reconstructed and OUT 1. Measurements are show in both presence and absence of the other interfering data channels to determine signal degradation.

Ch. D.

Conclusion

We demonstrated a SiP photonic MIMO demultiplexer performing all-optical unscrambling of four mixed modes. On-chip light monitoring through transparent CLIPP detectors was exploited, enabling accurate and robust tuning of the demultiplexer without affecting mode orthogonality. Demultiplexing of four 10 Gbit/s channels with less than -20 dB crosstalk and a power penalty of 1.5 dB at BER level of 10^{-8} is achieved.

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