Silicon Waveguide based Two-Input Simultaneous Quaternary Hybrid Doubling/Subtraction (2A-B, 2B-A) Using Degenerate FWM and QPSK

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Abstract: By exploiting two degenerate four-wave mixing in a silicon waveguide and quadrature phase-shift keying (QPSK) signals, we experimentally demonstrate two-input (A, B) simultaneous optical quaternary hybrid doubling/subtraction (2A-B, 2B-A).
OCIS codes: (130.3120) Integrated optics devices; (200.4560) Optical data processing; (190.4380) Nonlinear optics, four-wave mixing

1. Introduction

Optical signal processing is regarded as a key building block for next-generation high-speed optical networks. Optical nonlinearities are promising candidates to enable various optical signal processing functions, such as logic gate, switching, optical computing, (de)multiplexing, and coding/decoding [1]. Previously, optical binary logic gates were reported in various platforms for on-off keying (OOK) and phase-shift keying (PSK) formats, including highly nonlinear fiber (HNLF), semiconductor optical amplifier (SOA), periodically poled lithium niobate (PPLN) waveguide, chalcogenide (As_2S_3) waveguide, and silicon waveguide [2-4]. With unabated exponential growth of data traffic, coherent systems using advanced multi-level modulation formats, e.g. m-ary phase-shift keying (m-PSK) and m-ary quadrature amplitude modulation (m-QAM), and orthogonal frequency division multiplexing (OFDM) have become of great importance for efficient increase of transmission capacity and spectral efficiency of communication systems [5, 6]. In addition, multi-level modulation formats with multiple constellation points in the I/Q plane can be used to represent high-base (quaternary, octal, hexadecimal) numbers. Hence, there might be interest to enable optical signal processing for high-base numbers using multi-level modulation formats, e.g., m-ary quadrature amplitude modulation (m-QAM) and m-ary phase-shift keying (m-PSK). Recently, we demonstrated optical computing and coding/decoding for high-base numbers using HNLFs with length longer than 100 m [7-10]. Driven by the trend of large-scale integration, it is highly desirable to perform these functions using compact devices. Silicon waveguide is of great interest owing to its compactness and potential for complementary metal-oxide-semiconductor (CMOS) compatibility [11]. Moreover, silicon waveguides also feature high nonlinearity to enable various optical signal processing applications. In this scenario, a laudable goal would be to achieve optical high-base computing using nonlinearities in silicon waveguides.

In this paper, using QPSK signals with four-phase levels ($\pi/4$, $3\pi/4$, $5\pi/4$, $7\pi/4$) to represent quaternary base numbers (0, 1, 2, 3), we experimentally demonstrate all-optical two-input (A, B) optical quaternary hybrid doubling/subtraction (2A-B, 2B-A) using a silicon waveguide by exploiting degenerate four wave mixing (FWM).

2. Experimental setup

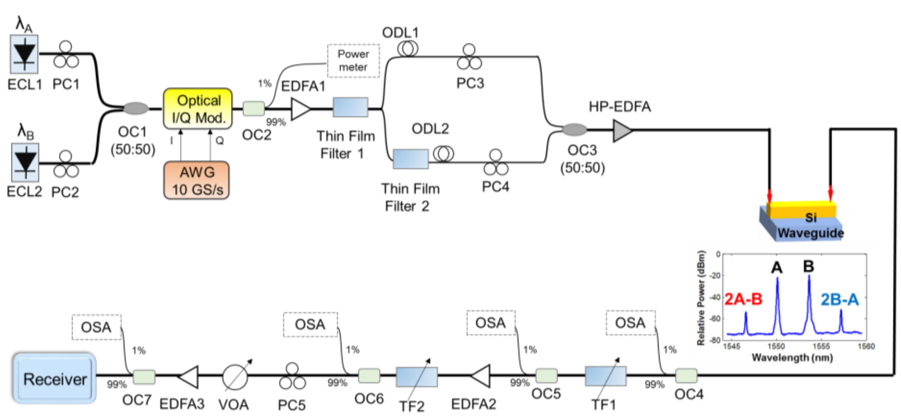

Fig. 1. Experimental setup for silicon waveguide based all-optical two-input (A, B) optical quaternary hybrid doubling/subtraction. Inset is the measured spectrum for degenerate FWM.

The experimental setup for silicon waveguide based all-optical two-input (A, B) optical quaternary hybrid doubling/subtraction is shown in Fig. 1. The wavelength of two input QPSK signal fed into silicon waveguide is 1550.12 nm and 1553.65 nm, respectively. From the measured spectrum in the inset of Fig. 1, one can see that two idlers (idler 1: 1546.59 nm, idler 2: 1557.20 nm) are generated by two degenerate FWM processes.

3. Experimental results and discussions

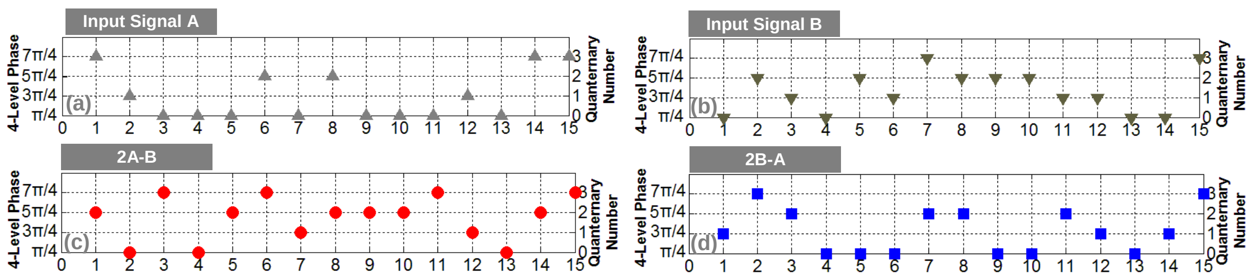

Fig. 2. Measured symbol sequence for two-input optical quaternary addition/subtraction (2A-B, 2B-A).

Figure 2 shows the measured symbol sequence for two-input optical quaternary hybrid doubling/subtraction. It can be confirmed from Fig. 2 that simultaneous quaternary hybrid doubling/subtraction (2A-B, 2B-A) are successfully implemented using QPSK, degenerate FWM, and coherent detection.

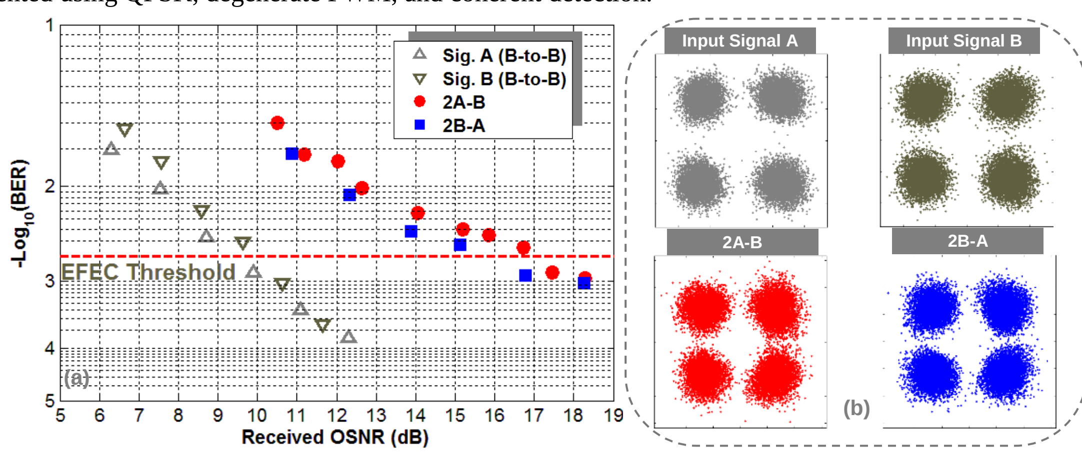

Fig. 3. Measured BER curves and constellations for two-input quaternary hybrid addition and subtraction of 2A-B and 2B-A.

Measured bit-error rate (BER) performance as a function of received optical signal-to-noise ratio (OSNR) is shown in Fig. 3(a). The measured OSNR penalty is around 7 dB at a BER of 2e-3 (enhanced forward error correction (EFEC) threshold) for two-input quaternary hybrid doubling/subtraction of 2A-B and 2B-A. From Fig. 3(b), the measured constellations of two converted idlers (two-input quaternary hybrid doubling/subtraction of 2A-B and 2B-A) are also QPSK formats. The obtained results shown in Figs. 2 and 3 confirm the successful implementation of simultaneous quaternary hybrid doubling/subtraction (2A-B, 2B-A) using QPSK, degenerate FWM, and coherent detection.

4. Acknowledgements

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