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Optical Time-Slot Swapping Based on Parametric Wavelength Exchange

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Abstract: We experimentally demonstrate successful simultaneous RZ-NRZ optical signal time-slot swapping based on the parametric wavelength exchange (PWE) in the highly-nonlinear dispersion shifted fiber (HNL-DSF). Clear open eye diagrams of periodic mixed RZ and NRZ signals are recorded.

OCIS codes: (190.4410) Nonlinear optics, parametric processes; (060.2330) Fiber optics communications.

1. Introduction

Parametric wavelength exchange (PWE), which realizes the simultaneous wavelength conversion between two signals relying on parametric effects in highly-nonlinear dispersion shifted fibers (HNL-DSF) [1,2], has been studied comprehensively in recent research [3]. Lately, optical time-slot interchange [4] and optical label swapping [5] have attracted significant investigation, and either FWM-based [4] or SOA-based [5] wavelength converter approach was presented. While in this paper, we propose and demonstrate an RZ-NRZ signal time-slot swapper based on pulsed pump PWE in HNL-DSF, which has unique merits of simultaneous power exchange between different wavelengths [3], low-noise operation [6], and polarization independence [7]. Comparing to the previous research on packet-switch application [8], a more practical pseudorandom binary sequence (PRBS) signal with the length of 2^7-1 bits is used instead of arbitrary data string employed in [8]. Meanwhile, for the reason of emphasizing the contrast in the output mixed signal eye-diagram, both NRZ and RZ signals are applied in our experiment. The output signal eye diagrams are utilized to analyze the performance of our time-slot swapper.

2. Principle and Experimental Setup

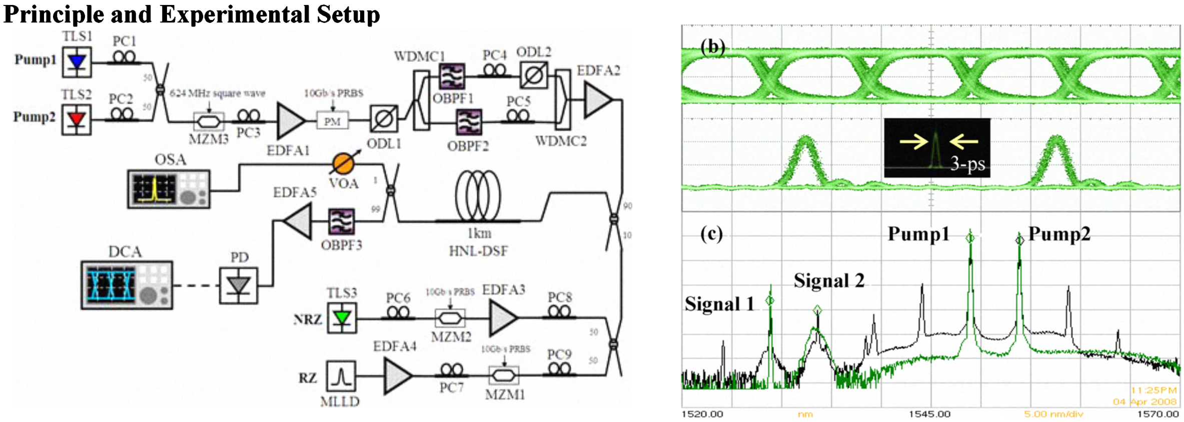

Fig.1. (a) Experimental setup of the RZ-NRZ timeslot swapping based on PWE. (b) Original NRZ eye diagram (upper part), RZ eye diagram (lower part) and RZ diagram (inset of (b)) measured by OSO. (c) Spectrums shown on OSA before (green solid line) and after (black solid line) the process of PWE.

In order to achieve synchronous interchange of two different signal formats, strictly aligned pumps with certain length of swapping window must be used. Additionally, orthogonal-polarized pump scheme is employed to minimize the undesired FWM components [3]. Fig.1 (a) shows the experimental setup. The RZ signal at 1534 nm is generated by intensity-modulating a 10-GHz pulse train sourced from a mode-locked laser diode (MLLD). Due to the low power output of the MLLD, it is amplified by EDFA4 before passing through polarization controller (PC7) to minimize the insertion loss through the Mach-Zehnder modulator (MZM1). For clear comparison, the 10 Gb/s NRZ signal is generated from a CW tunable laser source (TLS3) at 1529 nm, and intensity-modulated by MZM2. Before combining with the RZ signal branch, an erbium-doped fiber amplifier (EDFA3) is used to amplify the NRZ signal to an average power of 15 dBm. The PRBS length used for both the RZ and NRZ signal is 2^7-1. Besides signals, two CW pumps, located at 1549 nm (TLS1) and 1554 nm (TLS2), are firstly intensity-modulated by MZM3 with a gating quasi-square-pulse source, which is the trigger pattern with the repetition frequency of 624 MHz and

50% duty ratio from pattern generator. To suppress stimulated Brillouin scattering (SBS), two pumps are phase dithered with a phase modulator (PM) driven by a 10 Gb/s 2^{23}-1 PRBS; they are pre-amplified by EDFA1 before boosted by EDFA2 to an average output power of 26 dBm. Polarization controllers (PC1, PC2 and PC3) are inserted before AM1 and PM to reduce the insertion loss. Two optical band-pass filters (OBPF1 and OBPF2) are inserted after WDM coupler (WDMC1) to reduce amplified spontaneous emission (ASE) noise level from EDFA1. The alignment of both pulsed pumps is carried out by optical delay line (ODL2). Meanwhile, ODL1 is used to align pumps with signals. The state of polarization (SOP) of pumps and signals are controlled by polarization controllers (PC4, PC5, PC8, and PC9) at each branch to satisfy the orthogonal polarization condition before they are combined and launched into a 1 km HNL-DSF for PWE. The nonlinear coefficient γ, the zero-dispersion wavelength λ_0 and the dispersion slope $dD/d\lambda$ of HNL-DSF are 12 $W^{-1}km^{-1}$, 1541 nm and 0.03 ps/nm^{2}km, respectively. Eye diagrams for both original RZ and NRZ signals before the fiber input are shown in Fig. 1(b), with the inset eye diagram of RZ signal collected from optical sampling oscilloscope (OSO). The optical spectrum before and after the HNL-DSF are shown in Fig. 1 (c). After swapping, the exchanged signals are filtered and amplified by OBPF3 and EDFA5 before being sent to digital communication analyzer (DCA) for eye diagram analysis.

3. Results and Discussions

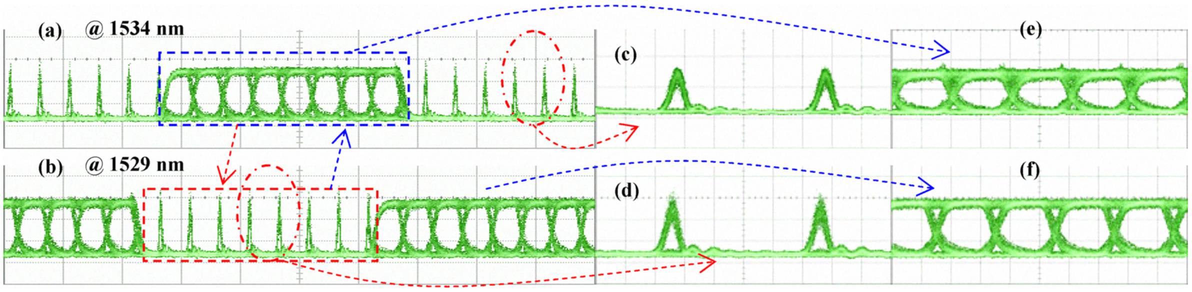

Fig.2. Measured eye diagrams of the swapped signals: (a) Original RZ signal (@ 1534 nm) with NRZ packet swapped in. (b) Original NRZ signal (@ 1529 nm) with RZ signal swapped in. (c) RZ eye diagram remained after PWE (@ 1534 nm). (d) RZ eye diagram swapped in (@ 1529 nm). (e) NRZ eye diagram swapped in (@ 1534 nm). (f) NRZ eye diagram remained after PWE (@ 1529 nm).

Fig. 2 lists the mixed and individual RZ and NRZ eye diagrams in details. The signals inside the timeslot, as shown in dashed boxes of Fig. 2 (a) and (b), are chosen to be swapped during the process of PWE. Clear and widely opening eye diagrams are observed for both wavelengths (Fig. 2 (c)-(f)). The ripples observed at the end of each RZ eye diagram are due to the limited operating bandwidth of a 53 GHz photo-detector (PD) using in our experiment. Additionally, the noise introduced during the PWE is inherited from the poor signal-to-noise ratio (SNR) of the two pumps after the high power EDFA which can be improved by reducing the ASE noise of pumps with a narrow bandwidth and high suppression level fiber Bragg grating [2].

4. Conclusions

We have demonstrated an optical time-slot swapper based on PWE in HNL-DSF. Successful time-slot swapping of one NRZ signal with another RZ signal is fulfilled. Clear and widely open eye diagrams have been obtained for both individual RZ, NRZ signals and mixed ones.

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