Demonstration of Cascadability and Phase Regeneration of SOA-Based All-Optical DPSK Wavelength Converters

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Abstract: We experimentally demonstrate cascadable regeneration of 10Gb/s DPSK signals by using a two-fold cascade of SOA-based wavelength converters. No additional power penalty and 3dB OSNR improvement are observed between 1 and 2 hops.
OCIS codes: (130.7405) Wavelength conversion devices; (250.5980) Semiconductor optical amplifiers

1. Introduction

All-optical regenerators and wavelength converters for phase sensitive communication formats are highly advantageous since they are not only low cost, but they show the potential to increase the allowable transmission lengths and reduce power dissipation over optoelectronic/electronic regenerators [1]. Differential Phase Shift Keying (DPSK) is a promising phase-modulation format because of its improved sensitivity and robustness towards nonlinear impairments. In such view of the importance of the DPSK format for future systems, it would be desirable to have small-footprint, low cost, low power-consuming all-optical DPSK regenerators and wavelength converters. Some approaches exploiting fiber-nonlinearities [2], or four-wave mixing in SOA have been demonstrated [3]. However, these approaches only offer a restricted wavelength conversion range and require high input power since their conversion efficiencies are still low. Another promising solution, used in this work, exploits the more efficient SOA-based cross-phase modulation effect, and has been demonstrated in integrated devices, with their regenerative properties reported [4-5]. In this approach, DPSK signals were converted to ASK pulses in advance by using a delay interferometer for controlling the SOAs, and interferometer was operated for obtaining a phase modulated output. Yet, experimental demonstration of cascadabilty has not been shown to the best of our knowledge. In this paper, we experimentally present a two-fold cascade of SOA-based all-optical DPSK wavelength converters and demonstrate its phase regeneration properties.

2. Experimental setup and phase regeneration properties

In the first part of our experiment, we present results of the phase regeneration properties of an integrated SOA-MZI based DPSK wavelength converter. The experimental setup is shown in Fig.1(a). An RZ-DPSK signal is generated using a pair of $LiNbO_3$ Mach Zehnder modulators (MZM) connected in tandem. A 2^7-1 pseudo-random bit sequence (PRBS) is used to encode the phase information onto a 1550nm optical signal from a Brillouin fiber laser with a linewidth of 300Hz. The signal is then launched into 20km of LEAF fiber after being amplified via EDFA to an average power of 16dBm in order to induce Gordon-Mollenauer nonlinear phase noise [6]. The phase-distorted DPSK signals are converted into differential amplitude shift keying (ASK) signals using a one-bit delay interferometer (DI). The differential ASK signals are then used as bit-aligned push/pull optical gating signals to a Mach Zehnder interferometer (MZI) wavelength converter. An input pulse transfers the RZ pulse pattern onto a probe signal (λ_2=1560nm) by inducing a 180^o nonlinear phase shift in its respective interferometer arm. The two SOAs are controlled very similarly as the push-pull operation of DPSK modulators. Thus, the phase information is transferred to a DPSK signal with a new wavelength (λ_2=1560nm) [4]. The 1550nm gating signals are filtered out with a 1.0nm wide optical bandpass filter. The wavelength-converted signals are detected and analyzed using an Agilent N4391A Optical Modulation Analyzer (OMA) and a DPSK receiver using a single-ended DI.

Fig.2(a) shows the constellation diagrams measured by Agilent N4391A OMA. The received power is kept constant at an average power of -6dBm during the measurement. Without regeneration, the error vector magnitude (EVM) and phase error increase from 10.9%ms to 30.1%ms and 2.66 deg to 23.6 deg respectively due to the phase distortion in the transmission fiber. After the regenerative wavelength converter, the EVM and phase error are improved to 23.1%ms and 7.93 deg, which demonstrate phase regeneration. Bit error rate (BER) measurements performed on the phase distorted signals and the wavelength-converted signals are shown in Fig. 2(b). A power penalty of 2dB, with respect to the back-to-back BER, is incurred from phase distortion. No apparent power penalty with respect to back to back, is observed after the phase regenerative wavelength converter.

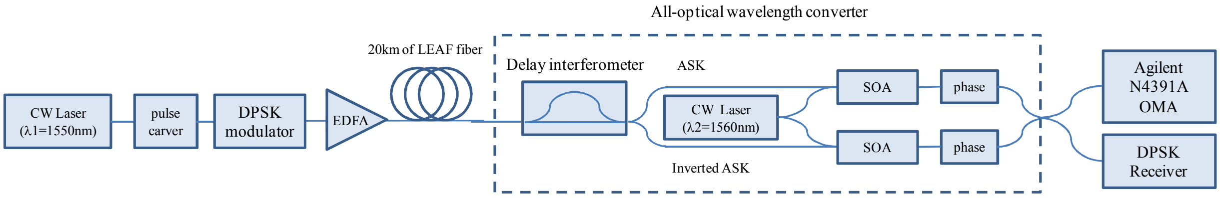

Fig.1(a) Experimental setup for investigating phase regeneration properties of all-optical DPSK wavelength converter

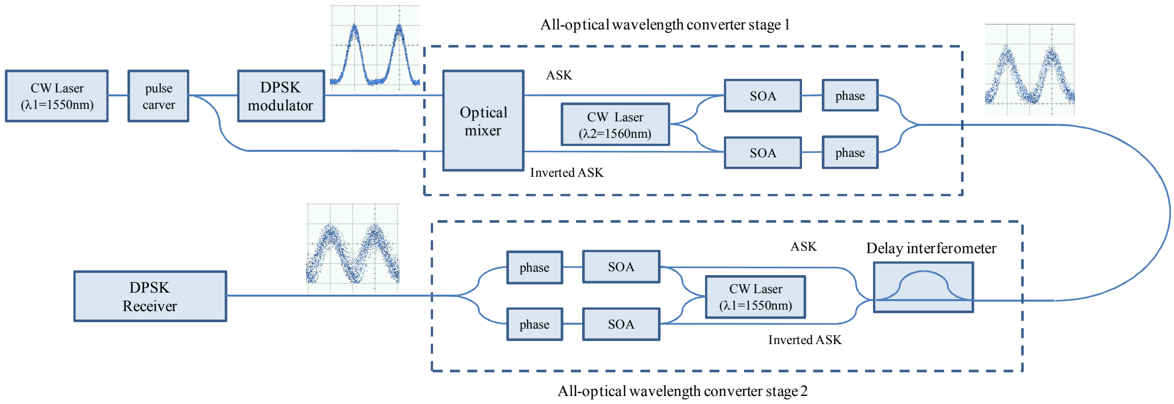

Fig.1(b) Experimental setup for cascading all-optical DPSK wavelength converters

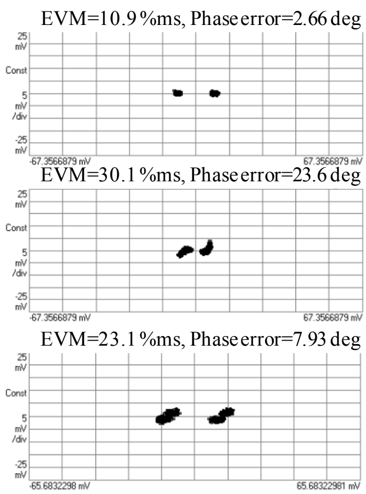

Fig.2(a) Constellation diagram for the input signal (top), phase distorted signal (middle), and regenerated signal (bottom).

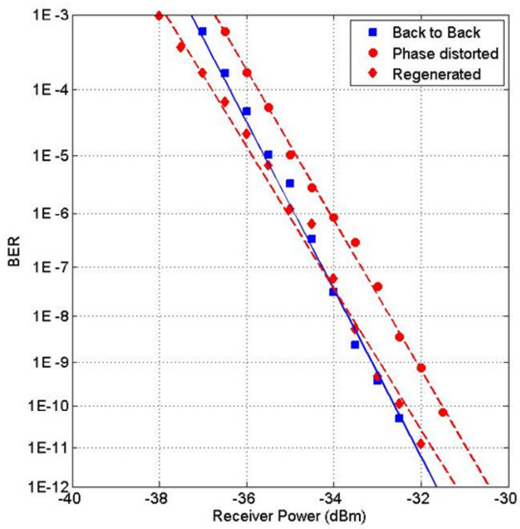

Fig.2(b) BER curves for input, phase distorted and regenerated signals.

3. Cascadability

Excellent regenerative properties of the wavelength converter are a good indications of its cascadability. The demonstration of wavelength converter cascadability is illustrated in Fig.1(b). The system consisted of two wavelength converters connected in series. DPSK signals at the input to the first regenerator stage are converted to differential ASK using a 90^o optical hybrid instead of a DI. The original pulse train is split and used as a local oscillator input to the 90^o optical hybrid. The wavelength is converted from λ_1=1550nm to λ_2=1560nm at the first stage, and back to 1550nm at the second stage.

The received eye diagrams of input signal and converted signals of the first and second wavelength converter are shown in Fig.3(a). Clear eye openings are observed for both converted signals. In this figure, the received powers are not fully adjusted. In Fig.3(b), measured OSNR is shown for each signal in Fig.3(a). Although the OSNR is degraded after the first wavelength conversion, it improves by 3dB after the second wavelength conversion, which clearly shows that the second wavelength converter has regenerative properties. Finally, the quality of the converted signal was evaluated by BER measurements, and its results are summarized in Fig.3(c). An error free wavelength conversion is obtained at about -31dBm of received power. The regenerator signals exhibited a power penalty of 1dB at 10^{-9} compared to the back-to-back signal due to the imbalance of two MZI-SOAs in the first stage. The second-stage regenerator showed a negligible increase in power penalty, which demonstrates its potential for cascadability.

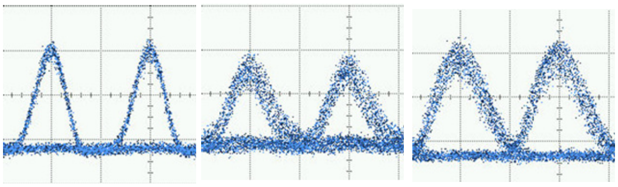

Fig.3(a) Eye diagrams at the output from single-ended DI in the receiver for input DPSK signals (left), first wavelength conversion (center) and second wavelength conversion (right).

# of hops	OSNR[dB]
Back to Back	57.7
1	37.9
2	41.0

Fig.3(b) OSNR at each number of hops

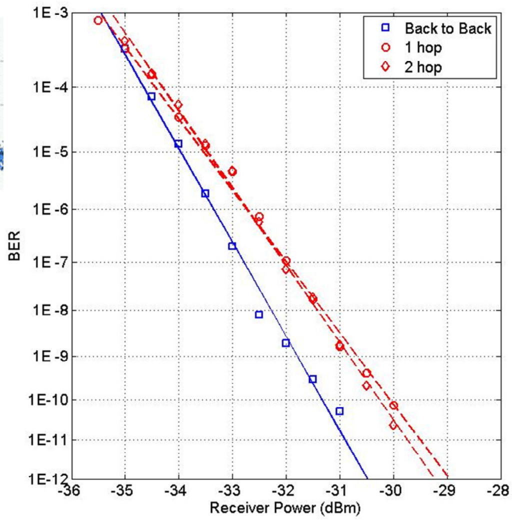

Fig.3(c) BER curves for input and converted signals

4. Summary and Conclusions

We have experimentally demonstrated the cascadability of SOA-based all-optical DPSK wavelength converters at 10Gb/s and its regenerative properties. A 3dB improvement in OSNR and no increase in power penalty were observed between the first and second wavelength converter. It is also demonstrated that the wavelength converter is phase regenerative in the presence of additive nonlinear phase noise. Using this wavelength preserving configuration, additional levels of cascading can be demonstrated in a re-circulating loop transmission setup, the topic of our work in the near future.

5. Acknowledgement

This work was funded by a Google Research Gift and supported by Agilent Technologies.

6. References

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