All-Optical ASK-DPSK Signal Regeneration Using a Semiconductor Optical Amplifier

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Abstract: We demonstrate 10-Gb/s and 20-Gb/s DPSK and ASK-DPSK signal regeneration based on cross-phase modulation in a SOA. The amplitude noise is reduced and the receiver sensitivity is improved by 3 dB.

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1. Introduction

Differential phase-shift keying (DPSK) data format has received much attention in minimizing the transmission impairment from fiber nonlinearities. The combination of amplitude-shift keying (ASK) and DPSK modulation formats is of great interest in a multilevel communication system [1]. In such a system, the data signals are transmitted at a bit-rate higher than that of binary modulation without the need to increase the existing bandwidth of the electronic and optoelectronic components. Since the bit-rate can be increased at a given symbol rate, the transmission impairment associated with a high symbol rate can be reduced [2]. In long-haul transmission, signal regeneration is often required as the signal is degraded by amplified spontaneous emission noise together with fiber dispersion and nonlinearities. Different DPSK regeneration schemes have been demonstrated using a nonlinear optical loop mirror [3], a semiconductor optical regenerative amplifier [4], and a nonlinear fiber via cross-phase modulation (XPM) [5-6]. The XPM approach offers an attractive solution as it does not require a large signal power. It is also desirable to use XPM to demonstrate simultaneous regeneration of ASK and DPSK signals.

In this paper, we demonstrate signal regeneration for DPSK and ASK-DPSK signals using XPM in a semiconductor optical amplifier (SOA). The regeneration process effectively suppresses amplitude noise while preserves phase information of the signal. Regeneration of DPSK and ASK-DPSK signals at 10-Gb/s and 20-Gb/s, respectively, are demonstrated in a SOA. With a 2^{31}-1 pseudo random binary sequence (PRBS) phase modulation, the receiver sensitivity is improved by 3 dB at 10^{-9} bit-error rate.

2. Experimental Setup

A 1546.9-nm laser diode is externally modulated by a 10-GHz clock using an intensity modulator. The resultant 10-GHz pulse train is then modulated with a 2^{31}-1 PRBS using a second intensity modulator to generate a 10-Gb/s RZ-ASK signal. The ASK signal is launched into a phase modulator (PM) driven with 2^{31}-1 PRBS data. The resultant ASK-DPSK signal operates at 20 Gb/s. The modulated signal is amplified by an erbium-doped fiber amplifier where the amplified spontaneous noise is introduced. The output signal is filtered and is directed to a variable optical attenuator. Afterwards, the signal is combined with 10-GHz mode-locked pulses from a 1558.1-nm fiber laser using a 3-dB coupler. The average power of the fiber laser is –8.3 dBm. The combined signal and pump pulses are launched to a SOA biased at 107 mA for signal regeneration. The regenerated output is filtered out by a tunable bandpass filter. A 100-ps delay interferometer is used to decode the DPSK part of the ASK-DPSK signal. The above setup can also be used to generate a 10-Gb/s RZ-DPSK signal and to study its regeneration property simply by removing the second intensity modulator for ASK modulation.

3. Results and Discussion

First, we perform signal regeneration for a 10-Gb/s DPSK signal using the proposed scheme. Amplitude noise is added to the signal by amplifying it with an EDFA and filtering the output with an optical bandpass filter. The eye diagram of the input DPSK signal is obtained by decoding it with a 100-ps delay interferometer. The result is displayed in Fig. 1(a)(i). The DPSK signal is combined with 10-GHz pump pulses from a mode-locked fiber laser and the combined lights are launched to the SOA for regeneration. At the SOA output, the regenerated signal is obtained by filtering with an optical bandpass filter. The eye diagram of the decoded output is obtained as shown in

Fig. 1(a)(ii). Bit-error rate measurement is performed at 10-Gb/s with a 10^{31}-1 PRBS. A 3-dB improvement is obtained at 10^{-9} bit-error rate. A plot of the measurement result is shown in Fig. 1(b).

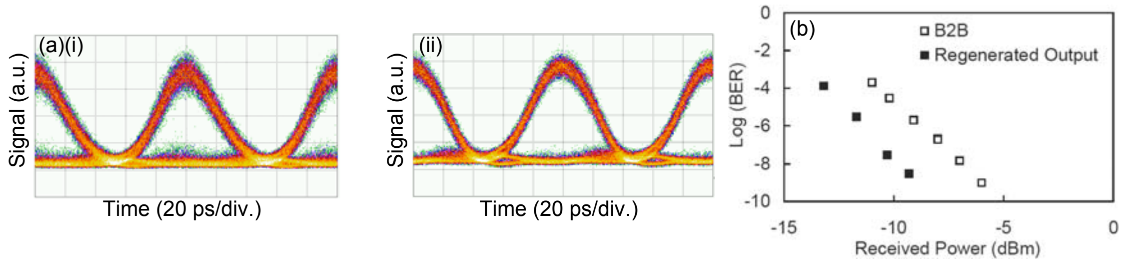

Fig. 1. (a) Eye diagram of (i) input DPSK signal (ii) regenerated DPSK signal (b) BER measurement.

To perform ASK-DPSK signal regeneration, the intensity modulator for ASK modulation is now connected to generate a 20-Gb/s ASK-DPSK signal. Again, the signal is launched to an EDFA and is then filtered with an optical bandpass filter. Amplitude noise is introduced in the process. The ASK part is measured directly with a digital sampling oscilloscope while the DPSK part is first decoded by a 100-ps delay interferometer before the measurement. The eye diagrams of the ASK and DPSK parts of the ASK-DPSK signal is shown in Fig. 2(a)(i) and (ii), respectively. After passing through the SOA together with the 10-GHz pump pulses, signal regeneration is obtained. The signal is then filtered out. Eye diagrams of the ASK and DPSK parts are measured. The results are displayed in Fig. 2(b)(i) and (ii), respectively. It is observed that the amplitude noise has been suppressed in both the ASK and DPSK parts of the signal.

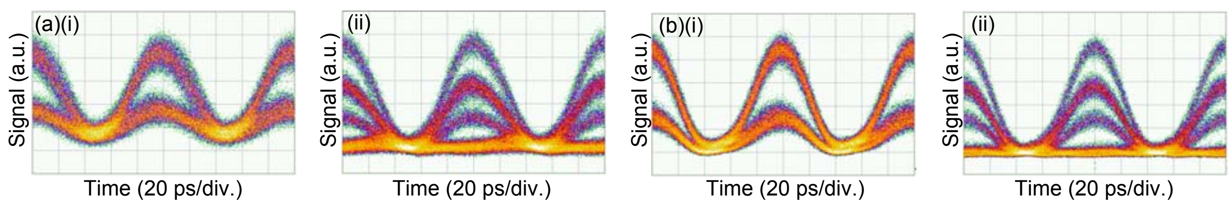

Fig. 2. Eye diagrams of (a) Degraded input (i) ASK part (ii) DPSK part (b) Regenerated output (i) ASK part (ii) DPSK part.

4. Conclusion

Optical regeneration of 10-Gb/s DPSK and 20-Gb/s ASK-DPSK signals have been demonstrated using cross-phase modulation in a SOA. Through the regeneration process, amplitude noise has been suppressed while the phase information of the signal is preserved. The eye opening is enhanced and a 3-dB improvement in power penalty is obtained at 10^{-9} bit-error rate using 10^{31}-1 PRBS data.

Acknowledgment

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