All-Optical Regeneration of 25-Gb/s BPSK/DPSK signals with Integrated MZI-SOA Wavelength Converter

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Abstract: We demonstrate all-optical regeneration with an optical PSK demodulator and integrated MZI-SOA for 25-Gb/s BPSK/DPSK signals. This concept can be applicable for regeneration for 100G PDM-QPSK using fully integrated devices.

1. Introduction

Phase shift keying (PSK) modulation formats, such as (D)BPSK and (D)QPSK, are becoming practical candidates for long distance transmission systems [1]. In such future systems, all-optical regenerators will offer a solution to greatly reduce the power consumption by OEO conversion and electronic regeneration. Two approaches to all-optically regenerate PSK signals have been demonstrated so far, which utilize fiber nonlinearity [2], and semiconductor device based Mach Zehnder interferometer semiconductor optical amplifier (MZI-SOA) wavelength converter [3,4]. The first approach, mostly known as a phase sensitive amplifier, has the advantage of large phase regenerative properties. The second approach is highly beneficial especially in terms of compact device implementation by monolithic or hybrid integration. Regeneration of DPSK signal at up to 40-Gb/s has been demonstrated by using a delay interferometer to convert the DPSK signal into amplitude modulation, and MZI-SOA wavelength converters to encode the phase information onto a new carrier [3]. And recently, a regenerative wavelength converter has been proposed and demonstrated in [5,6], which consists of a coherent demodulator of QPSK signals and nested MZI-SOAs for phase demodulation. For long distance transmission of PSK signals, nonlinear phase noise can be the most significant issues. Therefore, these all-optical regenerators will be required to have the capability to mitigate such phase noise distortions. In this paper, we present regenerative properties of the DPSK regenerator for ASE and nonlinear-phase-noise degraded input signals, and discuss further scalability of this scheme.

2. Experimental Setup

Fig.1 shows the schematic of the all-optical regenerator for (D)BPSK signals. A 25-Gb/s RZ-DPSK signal is first converted to OOK (I+) and inverted OOK (I-) signals by 90^{o} optical hybrid or 1-bit delay interferometer (DI). These bit-aligned OOK signals are used as gating signals at the MZI-SOA wavelength converter. Each arm of MZI-SOA is operated differentially, using time-shifted push/pull pulses, to overcome the slow gain recovery time of SOA. Due to the π phase difference between the two arms of SOA, OOK gating signals are mapped onto a (D)BPSK signal with a new wavelength 25GHz clock source.

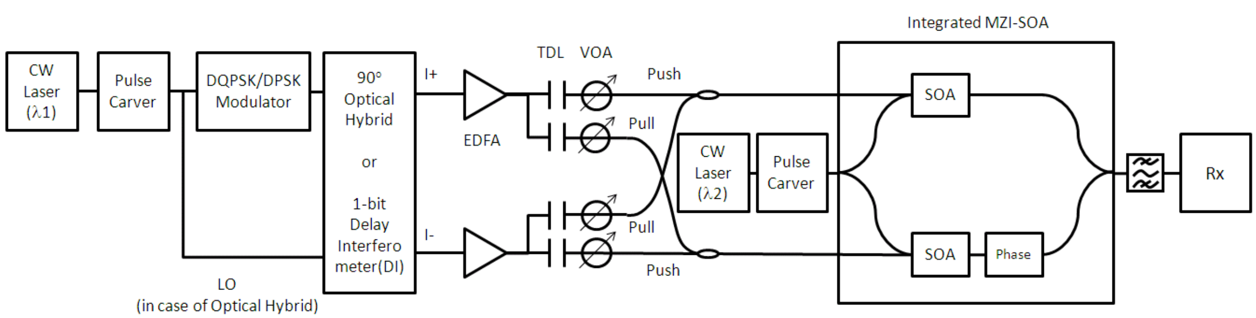
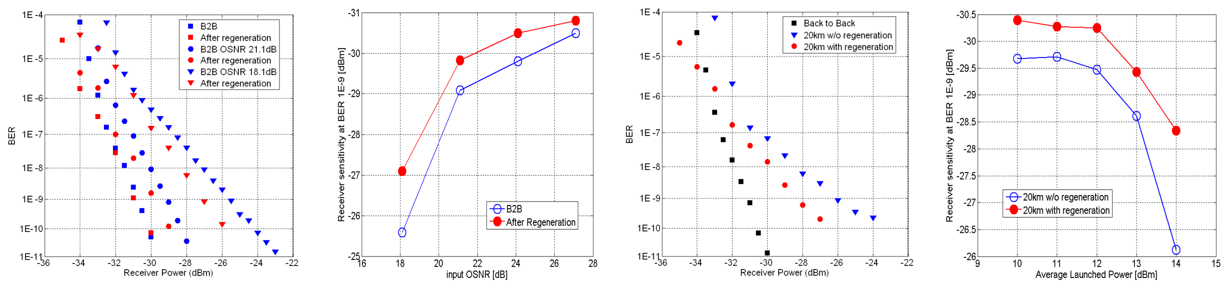


Fig. 1. Schematic of all-optical regenerator for (D)BPSK signals

3. Results and Discussion

To evaluate regeneration for a signal with linear phase noise, ASE was added with a 3-dB coupler to degrade the signal. Here we used a 1-bit DI for demodulating the DPSK signal. Fig. 2 (a) shows BER curves for B2B and regenerated signals with different input OSNR. Receiver sensitivity at 10^{-9} BER is also measured as a function of input OSNR, shown in Fig. 2(b). These figure show that the receiver sensitivity improved by as high as 1.5dB after regeneration for degraded input.

Next, to discuss the regeneration for nonlinear phase noise, the signal was transmitted through 20km of non-zero dispersion shifted fiber and associated dispersion shifted fiber with relatively high average power. Amplitude fluctuation is converted to nonlinear phase noise via the Kerr effect during the transmission, which is known as Gordon-Mollenauer nonlinear phase noise [7]. Fig. 2(c) shows BER curves for B2B, signals after 20km transmission with and without regeneration. The average launched power is set to +13dBm. An error floor at BER of 10^{-10} was observed after transmission, but the error floor almost disappeared after regeneration. Receiver sensitivity at 10^{-9} BER is also measured as a function of average launched power, shown in Fig. 2(d). The receiver sensitivity improved by as high as 2.3dB after the regeneration.



(a) (b) (c) (d)

Fig. 2. (a) BER curves for B2B and regenerated signals with different input OSNR. (b) Receiver sensitivity at 10^{-9} BER for B2B and regenerated signals as a function of input OSNR (c) BER curves for B2B and signals after transmission without/with regeneration. (d) Receiver sensitivity at 10^{-9} BER for the signal after transmission without/with regeneration as a function of average launched power.

This regeneration scheme can be scalable to (D)QPSK signals by using the 4 outputs of 90^{o} optical hybrid or two sets of 1-bit DIs with 90^{o} phase shift, and nested MZI-SOAs in which two (D)BPSK signals are combined in quadrature. For this scalability, high-density on-chip integration is a key. It should be noted, however, the demodulated QPSK signals have an inherently low extinction ratio, therefore suppressing the space levels of each OOK gating signal will be essential. Polarization division multiplexing signals can also be handled by using a polarization diversity circuit [5], which shows its potential for regeneration of 100-Gb/s PDM QPSK signal.

4. Conclusion

All-optical regeneration for 25-Gb/s DPSK signal has been demonstrated using optical PSK demodulation and integrated MZI-SOA wavelength converter. The receiver sensitivity improvements as high as 1.5dB and 2.3dB were observed for degraded signals with linear and nonlinear phase noise. This regeneration scheme has a potential for handling a future 100-Gb/s PDM QPSK signal.

5. Acknowledgements

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6. References

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