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Suppression of Interferometric Crosstalk and ASE Noise Using a Polarization Multiplexing Technique and an SOA

Xueyan Zheng, Fenghai Liu, David Wolfson, and Allan Kloch

Abstract—Noise suppression at 10 Gbit/s and 20 Gbit/s is demonstrated using a gain saturated semiconductor optical amplifier (SOA) and a polarization multiplexing technique, where no impairments like waveform distortion and extinction ratio degradation caused by the gain saturation of the SOA appear. Moreover, the method is bit rate transparent and the input power dynamic range is very large. Furthermore, the SOA can provide a high gain.

Index Terms—Interferometric crosstalk, noise suppression, polarization multiplexing, semiconductor optical amplifier.

I. INTRODUCTION

WAVELENGTH-DIVISION-MULTIPLEXING (WDM) networks have been installed on a global scale to satisfy the ever-increasing demand for communication capacity. In WDM networks, amplified spontaneous emission (ASE) from optical amplifiers and crosstalk at the signal wavelength (interferometric crosstalk) are serious problems [1]. So, it is very important to find effective techniques to suppress the impact of ASE noise and interferometric crosstalk. Several schemes have been demonstrated for noise suppression, including Mach–Zehnder interferometers [2], a wavelength converter based on cross gain modulation in a laser diode [3] and a gain saturated laser diode amplifier [4]. However, the Mach–Zehnder interferometer structure is complicated and the input power dynamic range is small. The method used in [3] inherently performs wavelength conversion and the conversion speed is limited by the recovery time of the carrier in the optical amplifier, moreover, there is a large undesired chirp is added to the signal. The method in [4] does not need wavelength conversion, but it suffers from extinction ratio (ER) degradation, waveform distortion at high input powers and it does not work at high bit rates because of the limited relaxation time.

In this paper, it is shown that signal fluctuations caused by interferometric crosstalk or ASE can be suppressed greatly at 10 or 20 Gbit/s using a gain saturated semiconductor optical amplifier (SOA) and a polarization multiplexing technique. Using polarization multiplexing of optical signals modulated by data and the complementary, the SOA experiences a constant input power instead of a transient power from the bit pattern and consequently impairments like waveform distortion and extinction ratio degradation from the SOA are eliminated. Moreover, the method is bit

rate transparent and the input power dynamic range is very large. In addition, the SOA can also provide high gain.

II. PRINCIPLE OF THE METHOD

When an SOA is gain saturated, the signal fluctuation caused by interferometric crosstalk or ASE noise can be reduced [3]. However, the ER of the output signal is reduced and the waveform is also distorted at high input power level due to the gain saturation. In order to avoid the above shortcomings, we multiplex the two optical signals with orthogonal polarization states which are modulated with data and the complementary respectively using a polarization beam combiner (PBC), hereby, obtain the multiplexed signals with a constant power as described in [5]. Since the SOA only experiences the constant optical power of the combined signals, no waveform distortions and ER degradation will be generated by the SOA. A polarization beam splitter (PBS) is used to demultiplex the signal. Fig. 1 shows the waveforms of the signals before the PBC, before and after the SOA and after the PBS when the input power into the SOA is -2 dBm, which is much higher than the 3-dB gain saturated power. It can be seen from Fig. 1 that no ER degradation and waveform distortion is induced. Furthermore, the method is pattern independent and no chirp is added to the signal due to the constant input power to the SOA.

III. EXPERIMENTAL SETUP

Fig. 2 shows the experimental setup. Light from a DFB laser is divided into two parts after being amplified by an EDFA. Each part is modulated by data ($2^{31}-1$ PRBS) or the complementary in an external modulator, and then set to one of two orthogonal polarization states. The two parts are combined in the PBC. A variable fiber delay line and a variable optical attenuator (Att1) are used before the PBC, in order to obtain a constant power of the combined signal without bit transition patterns. Two kinds of noise are generated to add fluctuation to the signal before launched into the SOA, one is interferometric crosstalk, the other is ASE noise. The interferometric crosstalk is added to the combined signal by adding a fraction of the original signal delayed by 500-m fiber. Att2 before the 3-dB coupler is used to control the input power to the SOA and Att3 is used to control the relative crosstalk power. ASE noise is generated by an EDFA. The signal is transmitted through in-line EDFA2, and then an optical filter with 1.3-nm bandwidth. Att4 before EDFA2 is used to control the input power. Thus, the optical signal-to-noise ratio at the input of the SOA can be controlled.

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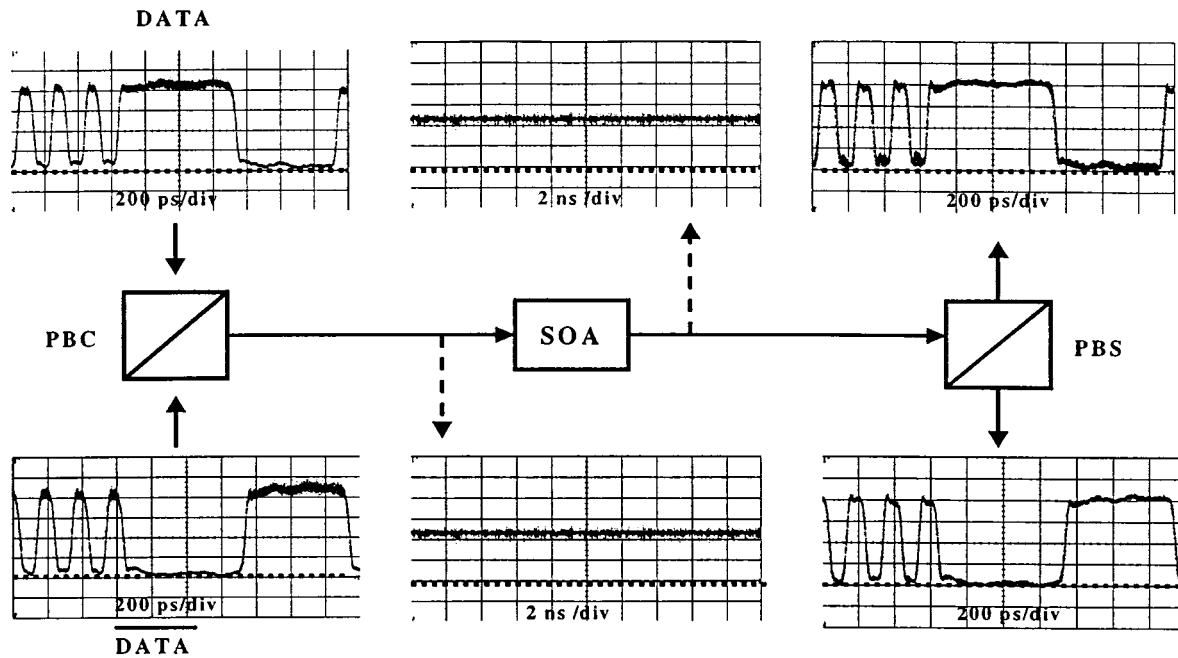


Fig. 1. Waveforms of the signal before polarization multiplexing, before and after the SOA and after the PBS. The input power into the SOA is -2 dBm. PBC: Polarization beam combiner. PBS: Polarization beam splitter. SOA: Semiconductor optical amplifier.

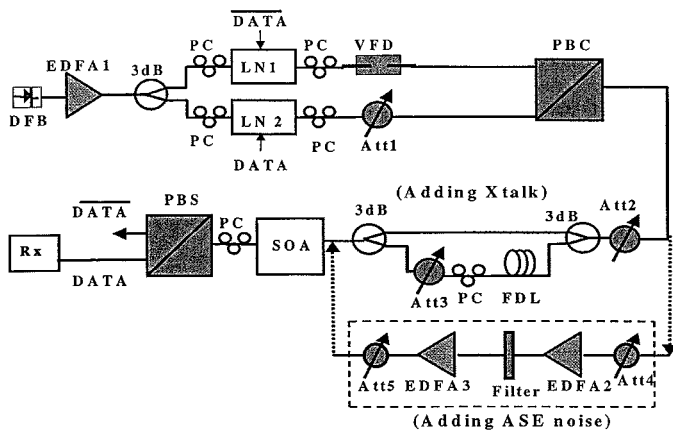


Fig. 2. Experimental setup. 3dB: 3-dB coupler. PC: Polarization controller. LN: Lithium Niobate modulator. VFD: Variable fiber delay line. PBC: Polarization beam combiner. Att: Variable optical attenuator. FDL: Fiber delay line. SOA: Semiconductor optical amplifier. PBS: Polarization beam splitter. Rx: Optical receiver.

The Att5 after EDFA3 is used to control the power into the SOA. The 3-dB saturation input power of the SOA is -10 dBm, the gain peak of the SOA is at 1550 nm and the gain polarization-dependence of the SOA is 0.5 dB. The two orthogonal polarized signals are separated by the PBS, both of them have the same performance and one of them is detected in a PIN receiver. When the crosstalk is added to the signal, the amplitude fluctuations caused by the beat noise between the signal and the crosstalk are suppressed significantly by the saturated SOA. Fig. 3(a) and (b) shows eye-diagrams of the 10 Gb/s signal with -13.8 dB crosstalk before and after the SOA. Seen from Fig. 3, a clear eye is restored after the SOA. Fig. 4 shows the penalties versus relative crosstalk power with and without the SOA at different input power levels. It can be seen from Fig. 4 that a 6 dB more crosstalk power can be tolerated using the SOA at a penalty of

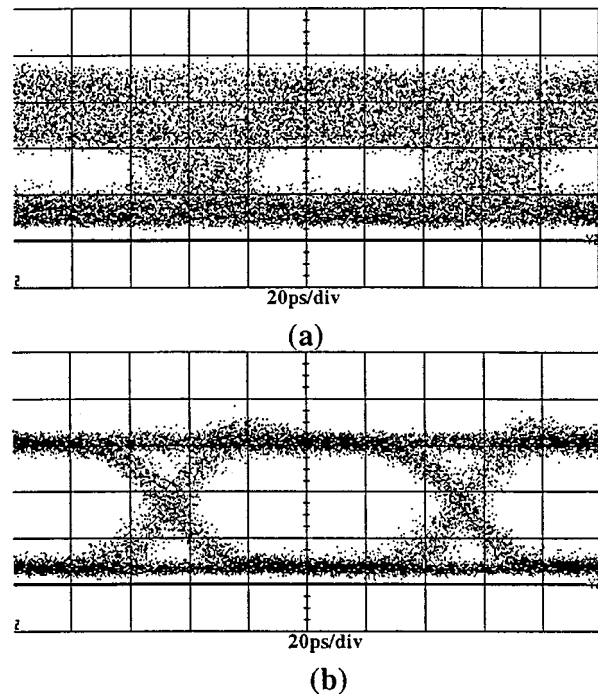


Fig. 3. Eye-diagrams of the signal with -13.8 dB crosstalk before (a) and after (b) the SOA at 10 Gb/s.

1 dB ($\text{BER} = 10^{-9}$) when the input power to the SOA is -6 dBm. Because the ER degradation and waveform distortion are avoided, the input power dynamic range is very large. Seen from Fig. 4, when the input power changes from -10 to 4 dBm, 4–6 dB more crosstalk power can be tolerated by using the SOA at a penalty of 1 dB ($\text{BER} = 10^{-9}$). Since the saturated output power of the SOA is $+7$ dBm, the SOA can also provide high gain. When the input power to the SOA is -10 dBm, the gain is $+17$ dB, meanwhile, 4 dB more crosstalk can be tolerated.

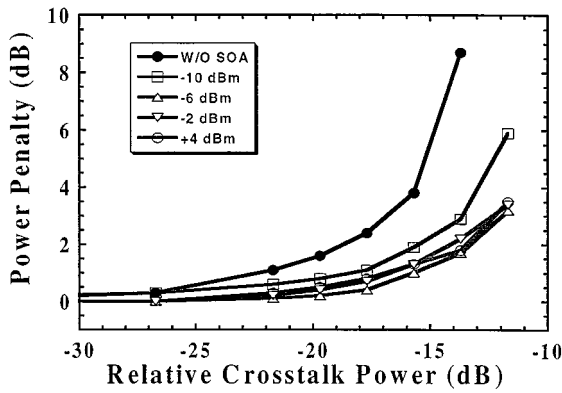


Fig. 4. Penalty as a function of relative crosstalk power for different input power level.

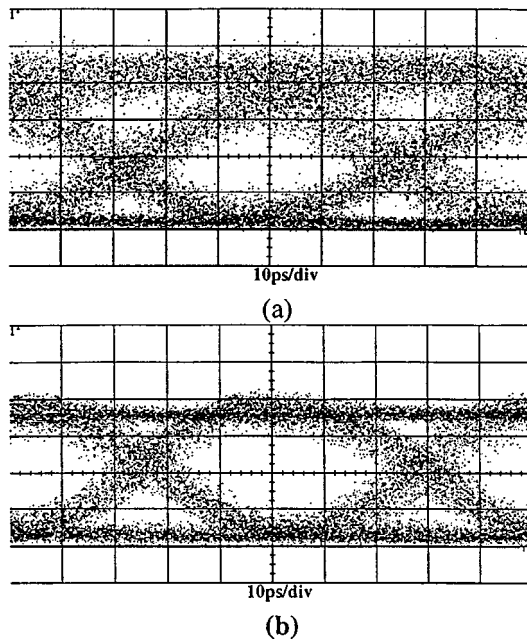


Fig. 5. Eye-diagrams of the signal with -17.8 dB crosstalk before (a) and after (b) the SOA at 20 Gb/s.

IV. RESULTS AND DISCUSSIONS

In general, this method can reduce any amplitude fluctuation with the frequency to which the SOA can respond, on the other hand, the electrical filter in the receiver will filter the noise with high frequency. Moreover, the waveform distortion and ER degradation are avoided, so, we can say that this method is bit rate transparent. The length of the SOA used in the experiment is 1.2 mm, and the 3-dB modulation bandwidth is larger than 30 GHz. So, effective noise suppression can be realized at very high bit rate using this method. Fig. 5(a) and (b) shows the eye-diagrams at 20 Gb/s before and after the SOA when the relative

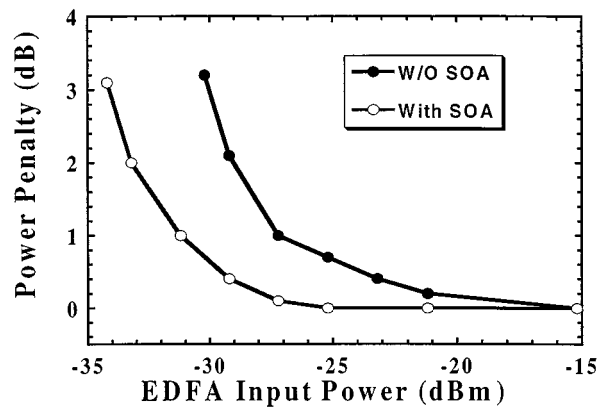


Fig. 6. Penalty as a function of the EDFA input power with and without the SOA at 10 Gbit/s. The input power to the SOA is -3 dBm.

crosstalk power is -17.8 dB; also here a clear eye can be found after the SOA. Due to lack of a 20 Gb/s receiver, no BER curves are measured in this case.

ASE noise is also suppressed effectively using the same method. Fig. 6 shows the receiver penalty at 10 Gb/s with and without the SOA as a function of the in-line EDFA input power. The input power to the SOA is -3 dBm. As seen, the noise is suppressed and 4 dB lower input power to the EDFA is allowed at a penalty of 1 dB ($\text{BER} = 10^{-9}$).

V. CONCLUSION

We have successfully demonstrated that the impact of interferometric crosstalk and ASE noise can be suppressed using a saturated SOA and a polarization multiplexing technique. The method gives no waveform distortion or extinction ratio degradation. Besides the method is bit rate transparent and the input power dynamic range is very large, the SOA can also provide a high gain.

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