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Wavelength Conversion Characteristics of SOA-MZI Based All-Optical NRZ-OOK/RZ-BPSK Modulation Format Converter

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Abstract Wavelength conversion characteristics of SOA-MZI based NRZ-OOK/RZ-BPSK modulation format converter was investigated experimentally. The error free operation in the whole range of C-band has been successfully demonstrated.

Introduction

Optical communication systems mainly employ conventional on–off keying (OOK) signals in either non-return to zero (NRZ) or return to zero (RZ) signal format. Recently, differential phase-shift keying (DPSK) modulation formats have been extensively studied for their high robustness for fiber nonlinearities, which enhance the perfomance of the long haul transmission [1],[2]. Therefore, it is likely that DPSK modulation formats would be employed in the long haul backbone network, whereas OOK modulation formats would be employed in the metro area networks (MAN) in future optical networks. To transparently connect the long haul backbone network and the MANs, all optical modulation format conversion becomes a key technique. An all-optical NRZ-OOK/RZ-BPSK (Binary PSK) modulation format conversion using semiconductor optical amplifier based Mach-Zehnder interferometric(SOA-MZI) wavelength converter was proposed and experimentally demonstrated with 10.7Gb/s operation [3]. However, to flexibly connect different networks operating with different wavelength ranges, all-optical wavelength conversion becomes an important technique. In this paper we experimentally investigate the wavelength conversion characteristics of the proposed NRZ-OOK/RZ-BPSK modulation format converter.

Experiment

Gain spectrum of the SOAs used in the experiment are shown in Fig. 1. 400mA current was injected and CW light was launched into the SOA to measure the gain spectra. The 3dB gain range of SOA1 is from 1523.0nm to 1570.2nm and 1529.0nm-1565.0nm for SOA2. SOAs' gain spectrum are major limiting factors for the NRZ-OOK/RZ-BPSK modulation format and wavelength conversions.

The experimental set-up is shown in Fig. 2. The NRZ-OOK data signal that acts as the control pulse was generated by modulating a CW light at 1548.1nm in a lithium niobate (LN) modulator with a 10.7Gb/s, 2^{31}-1

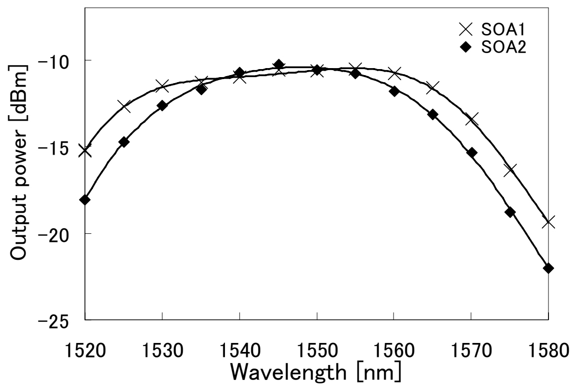

Fig. 1. Gain spectrum of SOAs.

long pseudo random binary sequence(PRBS). RZ clock pulse with a duty cycle of 50% was generated by modulating the CW light in an LN modulator by using the clock recovered from the control pulse. Each input polarization was optimized by a polarization controller (PC). The RZ clock pulse was coupled with a CW assist light at 1551.5nm. Control pulse and probe pulse were synchronously launched into SOA1. Using the cross phase modulation (XPM) in SOA1, the intensity modulated data was transferred to phase modulated data. Due to the simultaneous cross gain modulation (XGM) in SOA1, the output RZ-BPSK signal consists of different peak intensity levels depending on the "0" or "1" in OOK data signal. SOA2 was used to adjust the peak intensity level of the converted RZ-BPSK signal thanks to in-phase or anti-phase interference. We changed the wavelength of the RZ clock pulse from 1530nm to 1569nm with approximately 5nm intervals and conducted the modulation format and wavelength conversions. SOA1 was driven at 400mA injection current. We adjusted the phase of the probe pulse on the lower arm of the MZI by the phase shifter after fixing the injection current of the SOA2. After amplified by EDFA4, the converted RZ-BPSK signal was demodulated using a 1 bit delay interferometer and a balanced receiver.

The signal waveforms observed by the balanced receiver are shown in Fig. 3 for wavelengths of 1530.33nm, 1546.12nm, 1555.75nm, and 1569.59nm. Clear eye opening was observed for all wavelengths.

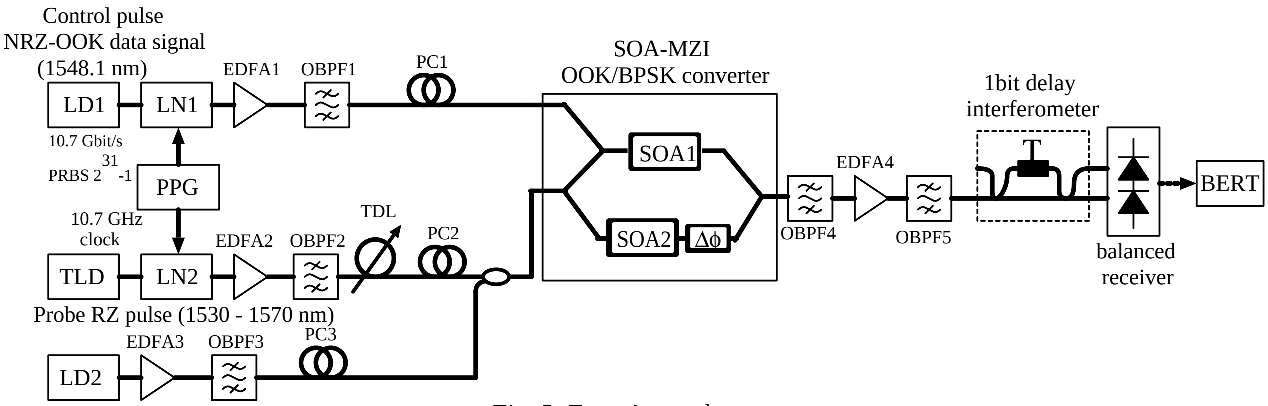

Fig. 2. Experimental set-up.

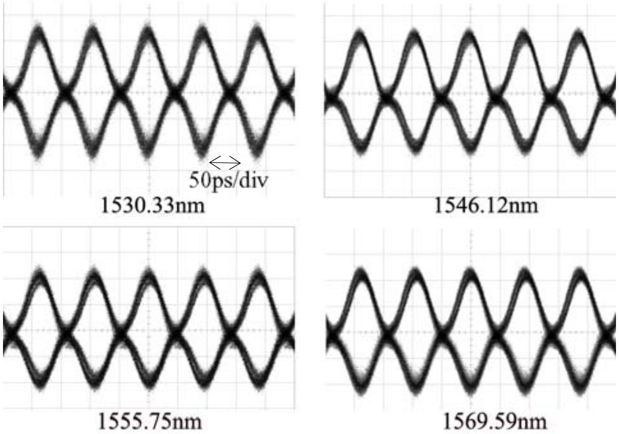

Fig. 3. Signal waveforms observed by the balanced receiver.

Figure 4 shows the measured bit error rate (BER) for the above-mentioned wavelengths. The linearity of the BER curves indicates the normal operation of the modulation format and wavelength conversions and error free operation can be confirmed for all wavelengths. At 1530.33nm wavelength, 3.45dB power penalty was observed for BER of 10^{-9}. This power penalty is induced by the noise characteristics of EDFA4.

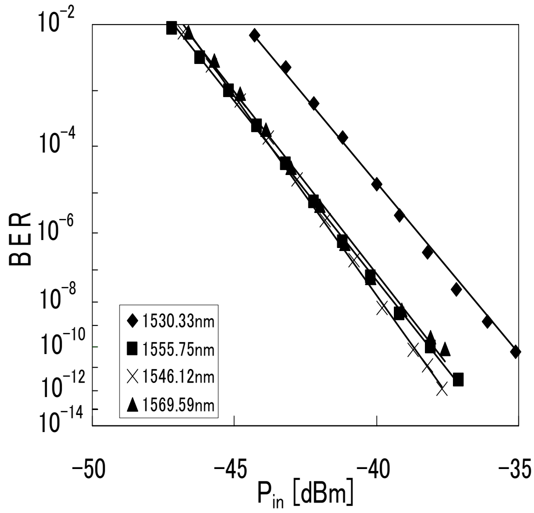

Fig. 4. BER curves.

To evaluate the wavelength dependent quality of the converted RZ-BPSK signal, we measured the received OSNR of the RZ-BPSK signal before the 1 bit delay interferometer. Figure 5 shows the received OSNR for BER of 10^{-9} against the wavelength. The observed maximum OSNR penalty is 0.96dB in the 1530nm-1569nm wavelength range.

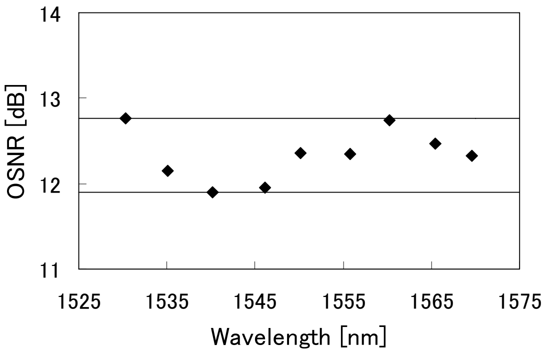

Fig. 5. Received OSNR for BER of 10^{-9}.

Conclusions

In this paper, we have experimentally investigated the wavelength conversion characteristics of the SOA-MZI based all-optical NRZ-OOK/RZ-BPSK modulation format converter. The maximum OSNR penalty in the whole range of C-band is only 0.96dB, and it is fairly small.

References

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