All-Optical XOR Gate Using Integrated SOA Three-Arm-MZI Wavelength Converter

Iori Takamatsu (1), Suresh M. Nissanka (1), Akihiro Maruta (1), Katsuhiro Shimizu (2), Toshiharu Miyahara (2,3) Toshitaka Aoyagi (2,3), Atsushi Sugitatsu (2,3) , and Ken-ichi Kitayama (1)
1: Graduate School of Engineering, Osaka University, 2-1 Yamada-Oka, Suita, Osaka, 565-0871 Japan.
Email: takamatsu@pn.comm.eng.osaka-u.ac.jp
2: Mitsubishi Electric Corporation, Itami, Hyogo, 664-8641 Japan.
3. Optoelectronic Industry and Technology Development Association (OITDA)

Abstract
We propose an all-optical XOR gate using integrated SOA three-arm-MZI wavelength converter and experimentally demonstrate an error-free operation converting from two NRZ-OOK signals to one RZ-OOK signal by achieving the XOR operation.

Introduction

In order to realize high-speed digital signal processing in photonic networks, all-optical logic gate will be promising. Especially, for achieving highly efficient transmission by use of network coding [1] in a multi-cast communication network, XOR (exclusive OR) gate plays an important role [1]. Recently, several types of all-optical XOR gate have been proposed [2].

In this paper, we propose a novel all-optical XOR gate using integrated semiconductor optical amplifier (SOA) three-arm Mach-Zehnder interferometer (MZI) wavelength converter, which is a newly developed single chip device for NRZ-OOK-to-RZ/QPSK conversion [3]. We experimentally demonstrate an all-optical XOR gate performance by launching two NRZ-OOK signals into the module and converting those to a RZ-OOK signal as the result of XOR operation.

Principle of all-optical XOR gate

Fig. 1 shows the principle of the proposed all-optical XOR gate using integrated SOA three-arm MZI wavelength converter. We use cross-phase modulation (XPM) in SOAs to convert intensity-modulated data into phase-modulated data. NRZ-OOK signals 1 and 2 are launched into port 1 and port 2 respectively. A RZ probe pulse sequence of λ_0 coupled with a CW assist light is launched into port 3. In SOA 1 and 2, the phase of the RZ probe pulse changes due to XPM incurred by the NRZ-OOK signals. Therefore, each output RZ probe pulse has a phase of “0” or “π” corresponding to “0” or “1” of the NRZ-OOK signal. In arm 2, the current of the phase shifter is adjusted to change the phase just “π”. In SOA, cross-gain modulation (XGM) occurs together with XPM, resulting in a probe pulse output with different intensity levels corresponding to “0” and “1” of the NRZ-OOK signal.

In order to compensate for this power difference, we use SOA 3 in arm 3. After the in-phase and anti-phase interference at port 4 and selected only RZ pulse sequence with the wavelength of “λ_0” through a band pass filter, RZ-OOK signal with equal peak power is obtained. This output signal is the result of XOR logical operations between two NRZ-OOK input signals.

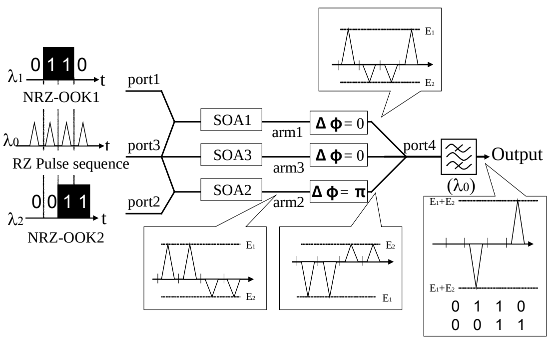


Fig. 1 The principle of the proposed all-optical XOR gate.

Experiment

Fig. 2 shows the experimental set-up for realizing the XOR gate using an integrated SOA three-arm-MZI wavelength converter. The NRZ-OOK data signals 1 and 2 were generated by modulating a CW light at 1548.115 nm in a Lithium Niobate (LN) modulator with 10.7 Gb/s. The bit pattern is the pseudo random bit sequence (PRBS) of length 2^7-1. Then, at the optical coupler, we divided it equally, delayed one signal by some bits using tunable delay line (TDL) and finally made two independent NRZ-OOK data signals.

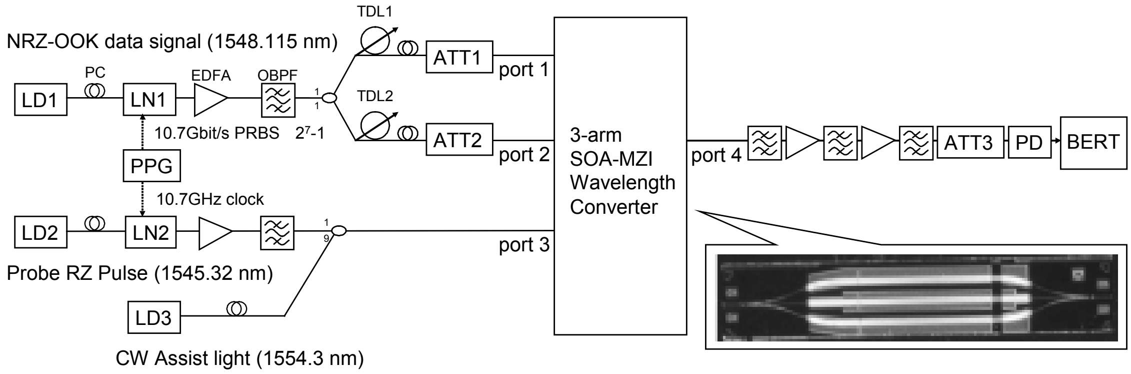
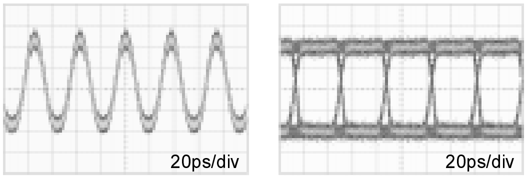


Fig. 2 Experimental setup. The inset shows a photo of the three-arm MZI module.



(a) RZ-pulse sequence (b) NRZ-OOK

Fig. 3 Input Signals.

The average powers of the data signals 1 and 2 launched into the port 1 and port 2 of the 3-arm SOA-MZI wavelength converter were +11.45 dBm and +6.1 dBm respectively. By modulating a CW light of 1545.32 nm in a LN modulator with 10.7 GHz clock from pulse pattern generator (PPG), a RZ probe pulse sequence was generated. The RZ probe pulse sequence with the average power of -2.95 dBm and a CW assist light of 1554.3 nm with +8.0 dBm were launched into the port 3. Input powers of all the signals were maximized by using polarization controllers (PC). Fig. 3 shows launched signal waveforms into the module. While Fig. 3 (a) shows RZ-OOK pulse sequence, Fig. 3 (b) shows NRZ-OOK signal. The output signal from the port 4 was amplified and converted to the electric signal by using the photo diode (PD). In the bit error rate (BER) measurement, we entered output bit patterns, which were calculated from the combination of data signals 1 and 2, into a BER Tester (BERT) in advance.

Experimental Results

Fig. 4 shows an eye pattern of the XOR signal. We could observe a clear eye opening in it. Fig. 5 shows the BER curves for NRZ-OOK signal and back-to-back XOR signal. They are almost straight-line approximated. We confirmed that XOR signal's BER achieved error free operation. The results show the feasibility of the XOR gate using the newly developed module.

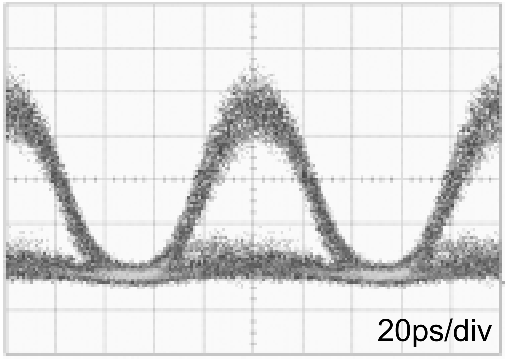


Fig.4 Eye pattern of the XOR signal.

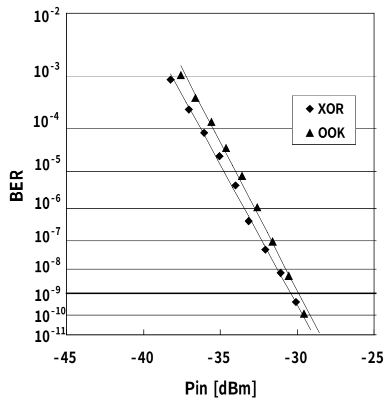


Fig.5 BER curves.

Conclusions

We have proposed an all-optical XOR gate using integrated SOA three-arm-MZI wavelength converter and successfully demonstrated the error free operation for two NRZ-OOK inputs at 10.7 bit/s.

References

1. R. Ahlswede et al., IEEE Trans. Inform. Theory, vol. 46, 1204-1216 (July 2000).
2. M. Zhang et al., IEEE Opt. Commun., vol. 43, S19-S24 (May 2005).
3. S. Nissanka et al., OFC/NFOEC 2009, OThM5.

978-3-8007-3173-2