Novel all-optical 10 Gb/s RZ-to-NRZ conversion using SOA-loop-mirror

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Abstract: This paper proposes and demonstrates a novel all-optical return-to-zero (RZ) to non-return-to-zero (NRZ) data format conversion using a semiconductor optical amplifier (SOA) loop mirror. 10 Gb/s error-free fiber transmission up to 78 km for the converted NRZ format data is achieved. Further, the proposed method shows improved transmission performance than the conventional Mach-Zehnder modulation technique.

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1. Introduction

Future all-optical networks are likely to employ both wavelength division multiplexing (WDM) and optical time division multiplexing (OTDM) and there will be a need for all-optical data format conversion between WDM and OTDM signals [1]. Non-return-to-zero (NRZ) and return-to-zero (RZ) formats are both widely used data formats. While the RZ format is preferred in ultra-fast OTDM networks to make use of bit-interleaving technique, the NRZ format has a lower bandwidth requirement and a higher timing jitter tolerance than RZ format. Therefore, RZ-to-NRZ format converter is essential in linking and interfacing the ultra-fast OTDM networks and the lower speed WDM networks [1]. Previous reports included all-optical RZ-to-NRZ conversion using a Mach-Zehnder PIC [2], SOA/fiber grating filter [3], SOA-XGM [1], and NOLM [4]. None except for Ref. [2] reported optical fiber transmission of the converted NRZ data. Also we propose and demonstrate, for the first time to the best of our knowledge, 10 Gb/s optical fiber transmission of the RZ-to-NRZ converted data using SOA-loop mirror.

2. RZ-to-NRZ conversion using SOA-loop mirror

Fig. 1 shows an experimental setup for the proposed RZ-to-NRZ converter scheme. A nonlinear optical loop mirror using an SOA (SOA-loop-mirror) is often used for all-optical switching in OTDM networks [5]. The switching principle is based on the optically induced phase difference (that is controlled by external control pulses) between a clockwise (cw) and a counterclockwise (ccw) pulse in a fiber loop mirror.

![Fig. 1 Experimental Setup](image1)

![Fig. 2 Principle of the proposed RZ-to-NRZ conversion](image2)
The operation principle of the proposed RZ-to-NRZ conversion is topologically identical to that of Ref. [2] except for the use of a grating filter to obtain good chirping characteristics as shown in Fig. 1. Ref. [2] employs a scheme using a Mach-Zehnder (MZ) interferometer while the proposed scheme is based on a Sagnac interferometer. In Fig. 1, the incoming RZ signal \( x(t) \) enters into the fiber loop mirror through the WDM coupler. Because the SOA is located at the displacement of \( \tau /2 \) (\( \tau \leq T \), \( T \) is a signal period) from the mid point of the fiber loop, the \( ccw \) beam takes a phase changing effect \( \tau \) later than the \( cw \) beam from the incoming RZ signal as shown in Fig. 2. Due to the phase change difference in both \( cw \) beam and the \( \tau \)-delayed \( ccw \) beam, the \( \tau \) gating window can be made. This operational principle is topologically identical to Ref. [2], but the proposed scheme has more simple and stable architecture.

3. Experiments and Results

In the experimental setup of Fig. 1, the SOA-loop-mirror consists of TDC, TDL, PC4, and SOA, which are connected by the WDM coupler for the RZ input signal \( x(t) \). A LiNbO\(_3\) electro-optic modulator and a mode-locked laser (~6 psec FWHM, 10 GHz) driven by a pulse pattern generator (PPG), generates a 10 Gb/s \( 2^{31-1} \) RZ data sequence at 1557.13 nm. The RZ input signal enters into the SOA-loop-mirror through the WDM coupler. For NRZ data generation, the continuous wave beam \( I_{in} \) at 1550 nm is generated from Tunable-LD. The SOA used in this experiment was 1000 \( \mu \)m-long and nearly polarization insensitive (~0.6 dB). The SOA current is set to 190 mA, coupling coefficient \( \alpha \) of TDC was adjusted to 0.41. The SOA-arrival time difference \( \tau \) was set to ~70 psec. The optical power at points ‘A’, ‘B’ and ‘C’ in Fig. 1 was set to 8.7 dBm, 5.0 dBm, and 8.5 dBm, respectively.

Fig. 3  Eye diagrams of the optical transmission for (a) the proposed RZ-to-NRZ converted signal and (b) the conventional NRZ signal generated by LiNbO\(_3\) MZ-modulator.
Fig. 3(a) shows eye diagrams for 10Gb/s RZ-to-NRZ converted signal and its optical transmissions over 26 km to 78 km dispersive standard single mode fiber. For comparison, the eye diagrams for the conventional NRZ signal generated by LiNbO3 MZ-modulator are also shown in Fig. 3(b). Note that in Fig. 3, the propagation eyes for the proposed method are better than those for the conventional NRZ modulation method even though the original RZ-to-NRZ converted signal is distorted. BERs for 26, 52, 78, and 104 km fiber transmissions are shown in Fig. 4 and the proposed RZ-to-NRZ converted signal show improved transmission performances compared to the conventional NRZ signal.

4. Summary

We have proposed and demonstrated a novel all-optical RZ-to-NRZ data format conversion using SOA-loop-mirror. 10 Gb/s error-free transmission up to 78 km for the converted NRZ format data is achieved. Also, the proposed RZ-to-NRZ conversion method shows improved fiber transmission performance than the conventional Mach-Zehnder modulation method, and will serve as a key block in linking and interfacing for all-optical OTDM and WDM networks.

5. References