40-Gbit/s SOA-Based All-Optical IRZ Generation Assisted by DI for Orthogonal Modulation in OTDM Systems

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Abstract: We employ a delay interferometer to enhance the data rate of the semiconductor-optical-amplifier-based inverse-return-to-zero (IRZ) generation to 40Gbit/s and investigate the improved performance of 40-Gbit/s IRZ/10-Gbit/s DPSK orthogonal modulation using reshaping-assisted demultiplexer in optical-time-division-multiplexed systems.

OCIS codes: (060.2330) Fiber optics communications; (060.4080) Modulation

1. Introduction

Inverse-return-to-zero (IRZ) modulation format has recently aroused much attention for its applications in spectral-efficient all-optical orthogonal modulation for its reduction of the crosstalk between two orthogonal signals [1, 2]. Such advantage is especially prominent when the two orthogonal formats have the same data rate, e. g. 10-Gbit/s IRZ/10-Gbit/s DPSK [2]. For orthogonal modulation with different data rate, this advantage, however, is diminished. To further reduce such crosstalk, we will show that by employing reshaping to improve the receiver sensitivity of the IRZ signal, the optimal extinction ratio can be lowered and less crosstalk is introduced to its orthogonal signal.

Among the existing IRZ generation approaches, the method using a dual-driven Mach-Zehnder modulator (MZM) is simple [3]. However, in addition to the complex pre-coding, the data rate of the IRZ signal is limited by the speed of the electrical pattern generator, thus it cannot be employed in optical time-division-multiplexed (OTDM) systems. Semiconductor optical amplifier (SOA)-based transmitter is small in size and is suitable for system integration [1]. However, such scheme also has the limited operation speed (< 10Gb/s) due to the slow carrier recovery time of SOA. Fiber-based nonlinear optical loop mirror can provide data-rate transparent IRZ generation [2], but its bulky size and poor power efficiency hinder its practicality.

In this paper, we propose and experimentally demonstrate a 40Gbit/s SOA-based IRZ signal generation method assisted by a delay interferometer (DI) in OTDM systems. A 10Gbit/s differential-phase shifted keying (DPSK) signal is superimposed on the 40-Gbit/s IRZ signal. It is shown that assisted by reshaping, low-extinction ratio 40-Gbit/s IRZ signal can be demultiplexed with enhanced performance, which, at the same time, introduces less crosstalk to DPSK signal and improves DPSK signal's performance as well.

2. Experimental setup

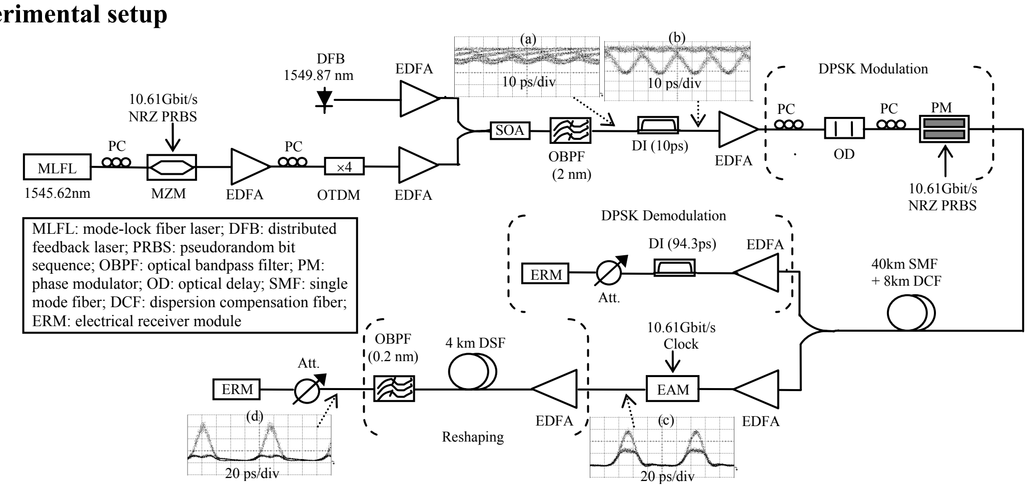

Fig. 1. Schematic diagram of the experimental setup

Fig. 1 depicts the experimental setup. A 3-picosecond pulse train was modulated, amplified and time-division multiplexed, to an aggregate data rate of 42.44Gbit/s. Cross-gain modulation (XGM) in a SOA was adopted for IRZ generation. Owing to the slow carrier recovery time of SOA, the resulted IRZ signal had a long tail, as shown in the inset (a) of Fig. 1. However, because the carrier depletion in the SOA also induced cross-phase-modulation (XPM) to the IRZ signal, the 10-picosecond delay interferometer (DI) after the OBPF would enhance the IRZ dips while suppress the tails through optical field interference, as shown in the inset (b) of Fig. 1. The generated IRZ was then phase modulated and fed into fibers. At the receiver, an electro-absorption modulator (EAM) demultiplexed IRZ signal to 10.6-Gbit/s RZ pulses with finite ER, as shown in the inset (c) of Fig. 1. A 4-km dispersion-shifted fiber (DSF) with the subsequent 0.2-nm optical filtering was employed to improve the ER. On the other hand, DPSK signal was demodulated by a DI with a relative delay of 94.3 ps and detected for BER measurement.

3. Results and discussions

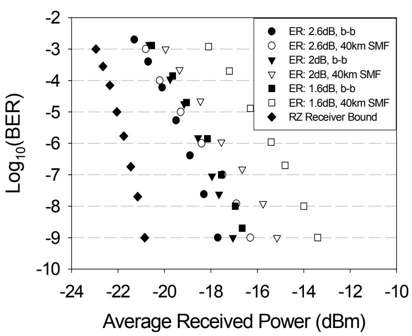

Fig. 2. BER performance of the demultiplexed IRZ signal with reshaping for different ER under 40 km transmission or back to back without DPSK signal.

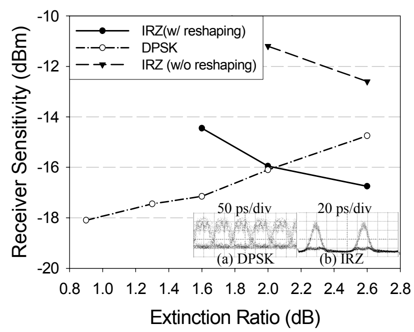

Fig. 3. Receiver sensitivity of DPSK and the IRZ signal without and with reshaping versus the ER (Inset (a) and (b): eye diagrams of the DPSK and the IRZ signals)

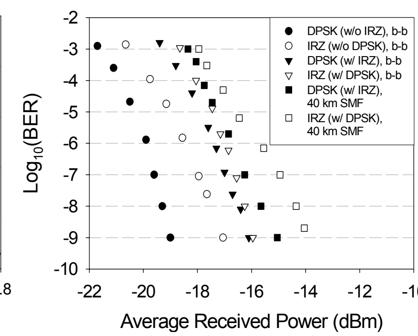

Fig. 4. BER performance of DPSK and IRZ signals with and without orthogonal modulation under 40km transmission or back to back at ER of 2 dB.

Fig. 2 shows the BER measurement of the reshaped IRZ signal without DPSK signal for different ER values by adjusting the input power of the RZ control pulses into the SOA. From the figure, it was shown that the receiver sensitivity of -16 dBm could be achieved for all three cases. After the 40-km SMF transmission, no error-floor was observed, indicating excellent performance of the proposed generation method. For orthogonal modulation, the dependence of the receiver sensitivity of the DPSK and the IRZ signals without and with reshaping on the ER of the IRZ signal was investigated, as shown in Fig. 3. It was seen that by using reshaping, the performance of IRZ signal was improved, leading to lower optimal ER at around 2 dB. Therefore, less crosstalk was introduced and the performance of the DPSK signal was improved as well. The inset (a) and (b) show the eye diagrams of the DPSK and the IRZ signals at the optimal ER, respectively. Fig. 4 depicts the BER performance of the DPSK and IRZ signals with and without orthogonal modulation under 40km transmission or back to back at ER of 2 dB. It was shown that the DPSK signal and the IRZ experienced 3-dB and 1-dB power penalties with orthogonal modulation, respectively. The possible sources for the induced penalty of IRZ signal included the imperfection of polarization stability and the OSNR degradation owing to the loss (~ 8 dB) in OD and PM. After 40-km transmission, the DPSK and the IRZ signals achieved error free with the receiver sensitivity of -15 dBm and -14 dBm, respectively. Such performance could be improved by using a DI with a short delay in the IRZ generation, which was believed to be able to generate narrower IRZ pulses, therefore offered improved optimal ER and less crosstalk to the DPSK signal.

4. Conclusions

We employed a DI to enhance the data rate of the SOA-based all-optical IRZ generation to 40Gbit/s and investigated 40-Gbit/s IRZ/10-Gbit/s DPSK orthogonal modulation in OTDM systems. The generation approach features its high speed all-optical operation and the suitability for system integration. We further demonstrated that by using reshaping assisted demultiplexer, the receiver sensitivity of the demultiplexed IRZ signal was enhanced and optimal extinction ratio was lowered, which reduced the crosstalk and therefore improved the performance of the DPSK signal at the same time. The project was partially supported by HKRGC (Project: CUHK4240/04E).

References

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