43 Gb/s 264 km field fiber transmission using 2R regeneration in a tunable all-optical signal regenerator

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Abstract: We demonstrate all-optical 2R regeneration for 43 Gb/s signal after 264 km field fiber transmission. The experimental results show that the all-optical 2R regenerator creates a negative power penalty and achieves an all-optical RZ-to-NRZ conversion.

OCIS codes: (250.5980) Semiconductor Optical Amplifier; (060.2360) Fiber Optics Links and Subsystems

1. Introduction

Rapid growths in data rates of fiber-optic communication systems are prompting the development of all-optical regeneration to facilitate cost-effective and flexible optical networking. Several all-optical regeneration and wavelength conversion technologies have been proposed based on non-linear fibers [1, 2], semiconductor optical amplifiers (SOA) [3-5], and electro-absorption modulators [6, 7]. Among these all-optical regeneration technologies, SOA based devices attracted attentions due to their relatively compact size and low power requirements. Several all-optical regeneration technologies with SOA based devices have already been demonstrated [3-5]. However, very few of them reported field trail experiments [8], which is a critical first step towards practical deployments. In this paper, we demonstrate an all-optical 2R (re-amplification and reshape) regeneration field trial experiment for 43 Gb/s signal after 264 km field fiber transmission, using a tunable all-optical signal regenerator (TASR). The single SOA based TASR is in an asymmetric Sagnac loop configuration (as show in Fig. 1) [9]. An optical coupler divides the incident CW beam (λ_{out}) into two counter-propagating beams. Due to the cross-phase modulation (XPM) effect, both the clockwise and counter-clockwise CW beams experience nonlinear phase shifts in the SOA when the signal light presents (λ_{in}). Since the Sagnac loop is asymmetric, the two CW beam will have different phase shifts and interfere when they encounter again at the coupler. The interferometric process converts the phase modulation to intensity modulation and reveals a regenerated signal on the CW wavelength (λ_{out}). The experimental results indicate that the TASR achieves 2R regeneration to the 43 Gb/s signal after field fiber transmission and create a negative system power penalty.

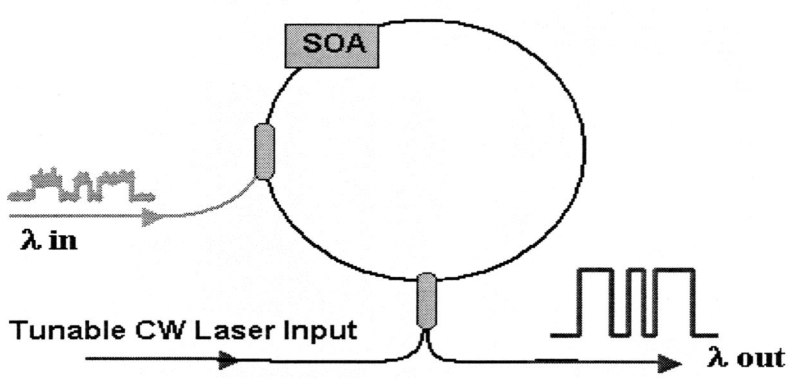

Fig.1. Schematic diagram of the tunable all-optical signal regenerator (TASR)

2. Experimental setup and results

Fig. 2 shows the experimental setup. The bit-error-rate-tester (BERT) generates a 43 Gb/s continuous data stream with 2^{23}-1 pseudo-random bit sequences (PRBS). The optical transmitter (Tx) inside the BERT takes the data stream and produces a 43 Gb/s optical signal in return-to-zero (RZ) format with a wavelength of 1550 nm. The optical signal then goes into the field fiber transmission spans. The average optical power going into the fiber spans is around 8 dBm. As illustrated in Fig. 2., each field fiber span consists of 66 km standard single-mode fiber (SSMF) and two inline amplifiers. Dispersion-compensating fibers (DCF) are inserted in between the inline amplifiers for chromatic dispersion compensation. The total chromatic dispersion of the SSMF spans is 4382 ps/nm (66 km × 4 × 16.6 ps/km/nm), and the inline dispersion compensations from the DCFs (from left to right in Fig. 2) are –1029 ps/nm, -1358 ps/nm, -1042 ps/nm and –983 ps/nm. There are total –4412 ps /nm inline dispersion compensation against 4382 ps/nm chromatic dispersion from the field fiber spans. Fig. 3 shows the map of the field fiber spans used in this experiment. Each fiber span starts at Burlingame, goes to Palo Alto and loops back, with a total distance of 66 km. After the field fiber transmission, an optical tunable band-pass filter (BPF) filters out the out-of-band ASE noise and forwards the signal to the adaptive dispersion compensator (ADC) for fine chromatic dispersion adjustment. The ADC put 30-ps/nm chromatic dispersion on the signal. The EDFA after the ADC boosts up the signal power to around 8 dBm, acting as a pre-amplifier for the TASR. The TASR takes the CW light (with 6 dBm power) from the tunable laser as a probe beam and imprints the signal on it through cross-phase modulation (XPM) based wavelength conversion. Due to its non-linear response, the TASR reshapes the signal during the wavelength conversion and performs format conversion from a return-to-zero (RZ) to a non-return-to-zero (NRZ). The regenerated signal exhibits a NRZ format with an inverted logic. The BPF at the output of the TASR selects out the regenerated signal and forwards it to the EDFA for amplification. The optical receiver (Rx) converts the signal to an electrical format, recovers the clock, and forwards the signal to the BERT for BER measurements.

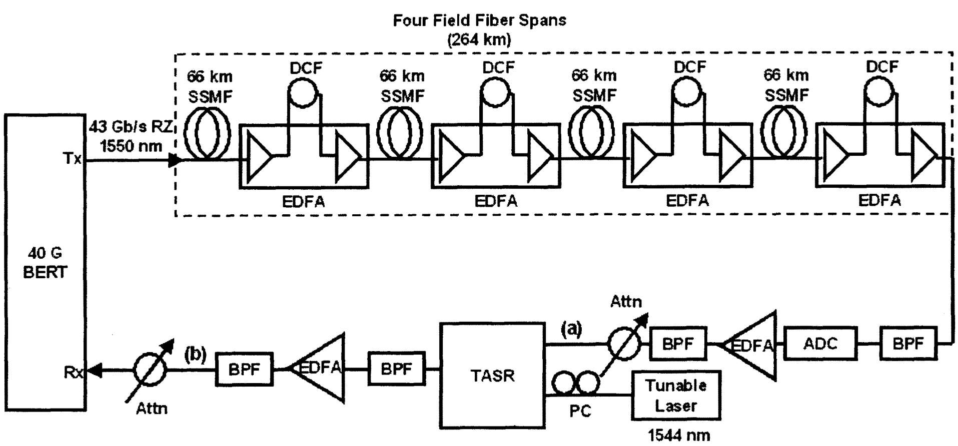

Fig. 2. Experimental setup. BERT: Bit Error Rate Tester; Tx: Optical Transmitter; Rx: Optical Receiver; SSMF: Standard Single-mode fiber; DCF: Dispersion Compensating Fiber; BPF: Optical Tunable Band-pass Filter; ADC: Adaptive Dispersion Compensator; EDFA: Erbium Doped Fiber Amplifier; Attn: Optical Variable Attenuator; PC: Polarization Controller; TASR: Tunable All-optical Signal Regenerator.

Fig. 4. illustrates the BER measurement results. The curve with open circles is for the signal before 2R regeneration and it shows an error-floor at 1E-7 due to OSNR (optical signal-to-noise-ratio) degradation and jitter accumulations. The BER curve of the regenerated signal exhibits a negative power penalty around 1 dB measured at BER level 1E-5, which is usually the forward-error-correction (FEC) limit for error-free detection, and has the same error-floor as the signal before regeneration. However, the power penalty calculated from the BER plot does not indicate the true system penalty. Note that, to obtain a same signal-to-noise-ratio (SNR) or eye opening after the optical receiver, signals in NRZ modulation format usually require more average input power than those in RZ format. Since the signal before 2R regeneration is in a RZ format and the signal after the regeneration is in an NRZ format, more negative power penalty can be expected if we normalize the receiver power. The insets of Fig. 4 show the eye-diagrams of the signals before (taken at location (a) in Fig. 2) and after the 2R regeneration (taken at location (b) in Fig. 2).

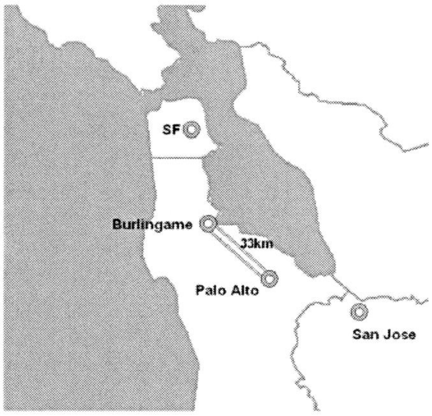

Fig. 3. Map of the field fiber

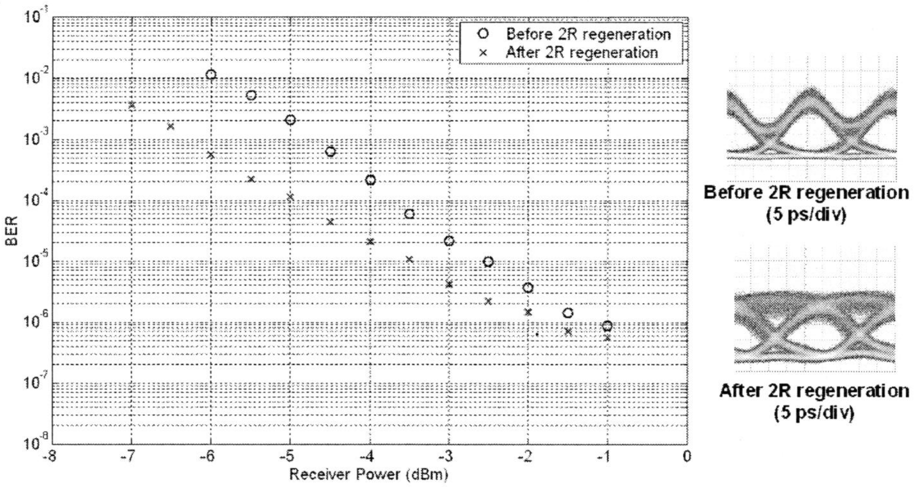

Fig. 4. BER results

3. Summary

We demonstrate an all-optical 2R regeneration experiment for regenerating 43 Gb/s signal after 264 km field fiber transmission. The optical regenerator is in an asymmetric Sagnac loop configuration with an SOA as the nonlinear medium. The experimental results indicate that the optical regenerator can perform an all-optical RZ-to-NRZ conversion, reshape the optical signal after field fiber transmission and create a negative system power penalty.

4. References

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