Regeneration using an SOA-MZI in a 100-pass 10,000-km Recirculating Fiber Loop[1]

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Abstract: We demonstrate all-optical regeneration in an SOA-MZI on a 10-Gb/s picosecond pulse train over 10,000 km in a 100-km recirculating loop. The bit-error rate after 100 loop-passes shows a 0.5-dB penalty.
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1. Introduction

To satisfy growing bandwidth demands in telecommunication networks, transmission capacity can be increased by using higher data rates on each wavelength channel. Picosecond pulses can enable channel data rates of 100 Gb/s and higher, but fiber transmission distance is often limited by amplified spontaneous emission noise, chromatic dispersion, nonlinearities, and polarization-mode dispersion. Thus, in-line regeneration of high-rate picosecond pulse trains is necessary. Ideally, such a regenerator should re-time, re-shape, and re-amplify picosecond pulses in an integrated package that can be easily manufactured, is straightforward to use, and remains stable over time.

The semiconductor-optical-amplifier Mach-Zehnder interferometer (SOA-MZI) is a compact integrated all-optical switch which has been demonstrated for bit-wise switching at data rates up to 80 Gb/s [1] and ultra-long-haul regeneration at 10 Gb/s [2]. In this paper, we demonstrate successful 3R regeneration in an SOA-MZI over a 100-km recirculating loop [3] with a total distance of 10,000 km. We combined an SOA wavelength converter [4] and an integrated SOA-MZI to form a compact wavelength-maintaining 3R regenerator. We present cross-correlation measurements of the output pulse train after 100 passes as well as gated bit-error-rate (BER) measurements at 0, 10, and 100 passes. Less than 0.5-dB penalty between the 0th and 100th passes was measured, indicating successful all-optical regeneration capable of correcting cumulative distortion effects.

2. Experiment and Results

We used an SOA-MZI provided by Alphion Corporation as a regenerator within a recirculating loop shown in Figure 1. In order to provide high-speed regeneration, the SOA-MZI was operated differentially. A pulse entering the C1 (control) input of the SOA-MZI pushes the interferometer out of extinction, allowing the signal pulse to pass. A second copy of the control pulse enters the C2 (control) input of the SOA-MZI after the signal pulse, pulling it back into extinction and eliminating the effect of the long SOA carrier-recovery time. Using a pump-probe bias scan technique [5], optimal switching SOA currents were found to be I_2 = 692.3 mA and I_3 = 708.1 mA. The pre- and post-amplifying SOA currents were set to I_5 = 81.4 mA (input), I_4 = 107.8 mA (C1), I_6 = 107.8 mA (C2), and I_1 = 150.3 mA (output). The input signal power was 3.5 dBm (448 fJ/bit) and the control input powers were 3.2 dBm (418 fJ/bit) for C1 and -2.9dBm (103 fJ/bit) for C2. A lower C2 input power was necessary to compensate for the recovery of the SOA during the delay between C1 and C2 pulses.

To test the performance of the SOA-MZI as a regenerator, we placed the device in a 100-km recirculating loop consisting of two 50-km sections of LEAF (D=3.7 ps/(nm km) at 1547.4 nm), 3.2 km of dispersion compensating fiber (DCF; D = -127 ps/(nm km) at 1547.4 nm), and erbium-doped fiber amplifiers to compensate loss. The 3-ps network data pulses were generated by a mode-locked fiber laser operating at 10 Gb/s with a wavelength of 1547.3 nm and modulated with a $2^{31}-1$ pseudo-random bit sequence before entering the loop. The data pulses were

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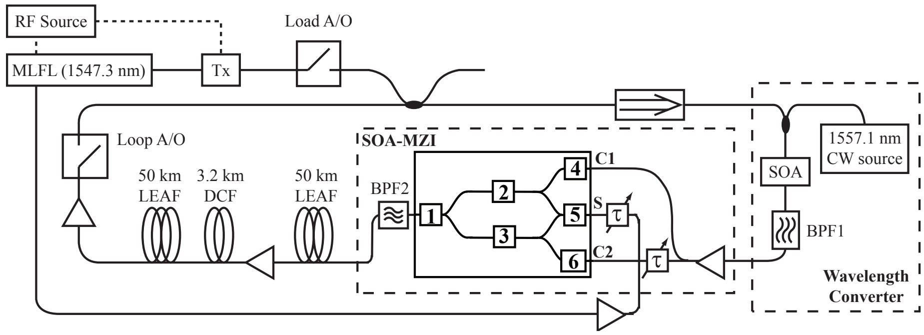

Fig. 1: Experimental schematic of the recirculating fiber loop with an SOA-MZI optical regenerator. MLFL is mode-locked fiber laser, BPF stands for bandpass filter, A/O is acousto-optic modulator, C1 and C2 are the first and second control inputs to the SOA-MZI, and S is the signal input. The numbered boxes represent SOAs within the SOA-MZI device.

translated to 1557.5 nm by the SOA wavelength converter. These network data pulses are then sent to the control inputs C1 and C2 of the SOA-MZI. The signal input of the SOA-MZI was an unmodulated clock pulse train at 1547.3 nm produced by the mode-locked fiber laser. For 3R regeneration, network data were modulated onto the low-jitter near-transform-limited signal pulses output from the SOA-MZI.

Figures 2(a) and (b) show the cross-correlations of the data pulses sampled by 200-fs pulses at the loop output without and with regeneration. From Figure 2(b), we see that the pulse shape is maintained after 100 passes through the loop and a total propagation distance of 10,000 km. Figure 2(c) shows BER curves as a function of power received by a pre-amplified receiver at the fiber loop output. The wavelength-maintaining SOA-MZI regenerator shows only a 0.5-dB penalty after 100 passes at a BER of 10^{-9} with respect to the regenerator alone (0 passes).

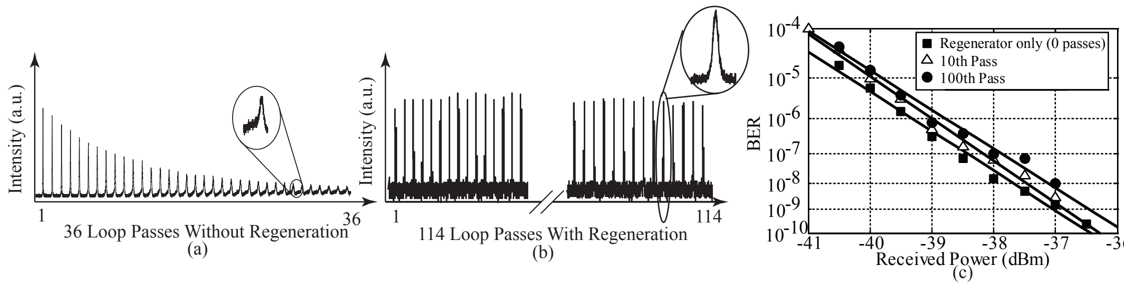

Fig. 2: Cross-correlations of the loop output (a) without regeneration and (b) with regeneration. (c) BER curve plots of the loop output at the 10th and 100th pass as compared to the wavelength-maintaining SOA-MZI regenerator alone.

3. Conclusion

We have demonstrated an integrated all-optical 3R SOA-MZI regenerator which extends the propagation distance of 10-Gb/s picosecond pulse trains. A power penalty of only 0.5 dB is incurred after 10,000 km of propagation in a 100-km recirculating fiber loop.

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