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Power Stable Fiber Loop Buffers with EDFA Followed by SOA

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Abstract: Fiber loop buffer with EDFA had relative low noise accumulation. For long packet-delay, suppression of relaxation oscillation was a key issue. This paper realizes the power stability by using SOA following EDFA in fiber loop.

1. Introduction

Optical packet switching (OPS) technology is the ultimate future-proof solution for a next-generation optical transport network that allows direct forwarding of data packets in the optical domain [1]. Optical buffers are key components in OPS systems that avoid packet collision along the same virtual path and wait for header processing time. Fiber delay lines are a practical candidate for all-optical packet buffers. Use of recirculating fiber loops [2, 3] can reduce the components needed to implement buffers, thereby reducing their size. In our previous paper, we described the use of an optical frequency shifter in the fiber loop to prevent unexpected oscillation caused by ring structure with including optical amplifiers and demonstrated, experimentally, an optical delay line that is tunable by the optical fiber ring [4].

Optical packets undergo many round-trip circulations in the loop. The ASE accumulation from every circulation can be mitigated by using low noise EDFA as the loss compensation amplifier. When long time buffering causes relaxation oscillation of optical power because of power feed back configuration of the loop with an optical amplifier and fluorescence life time of EDF [5]. This paper specifically describes a solution to overcome the oscillation. Our approach uses both EDFA and semiconductor optical amplifiers (SOAs) in this order for loop loss compensation.

2. Configuration of fiber loop buffers

Figure 1 shows the configuration of an optical tunable delay line using a fiber ring with an acousto-optic frequency shifter (AOS) and an erbium-doped fiber amplifier (EDFA). The storage and delay functions can be provided by the fiber loop. The optical switch located at the loop output plays the role of a delay-time selection function. Figure 2 shows the timing chart of the tunable delay line. The fiber length of the ring delays the packet when the optical packet signal pulse is incident into the fiber loop. The loop output is an optical pulse sequence constructed from replicas of the incident packet. If the time duration of packet T_p is shorter than the round trip time of the ring T_{ring}, then the optical switch following the ring selects the packet when the packet route is available.

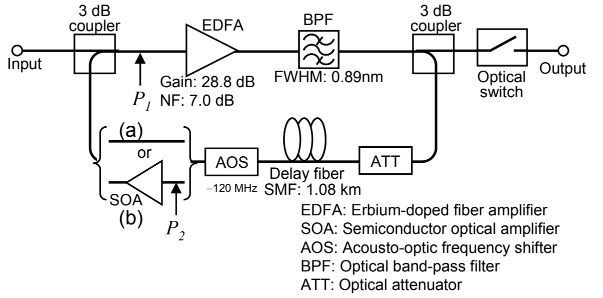

Figure 1. Configuration of the optical tunable delay line using a fiber loop with an acousto-optic frequency shifter.

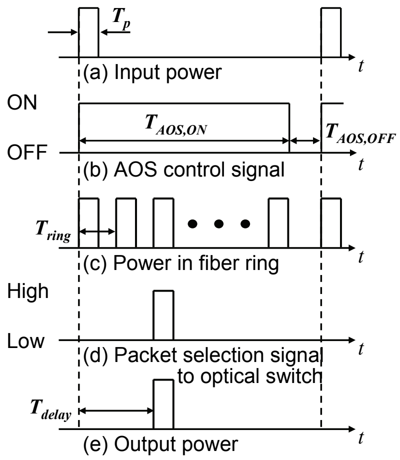

Figure 2. Timing chart for controlling the delay lines.

A packet can experience many round trips in the fiber ring. Optical amplifiers, then, are necessary to compensate the optical loss of the ring. The conventional configuration as shown in Fig. 1(a) uses an EDFA because of its high gain and low noise. The BPF rejects amplified spontaneous emission (ASE) noise and residual pump light from the EDFA. An AOS is inserted into the ring to prevent oscillation from the ring cavity [4].

Figure 3(a) shows the optical power waveform from the fiber loop with conventional configuration of Fig. 1(a). In this experiment, the rectangular pulse was used as an incident optical packet. The wavelength of the packet was 1552.5 nm. The center wavelength of BPF in the loop was identical to that of the packet. Packet length T_p was 5.0 μs. Optical loss of ATT was 0 dB in this case. Optical power waveform was measured by an oscilloscope after O/E conversion. The relaxation oscillation can be found with 4.3 kHz. Optical power variation in the oscillation was 2.8 dB. The top of each pulse was tilted by the oscillation after the eighth circulation. The basic origin of the oscillation is interplay between the oscillation field in the ring circuit and the atomic population inversion in the amplification medium. An increase in the field intensity induces a reduction in the population inversion because of the increased rate of stimulated transitions, causing a reduction in the amplification gain that tends to reduce the field intensity.

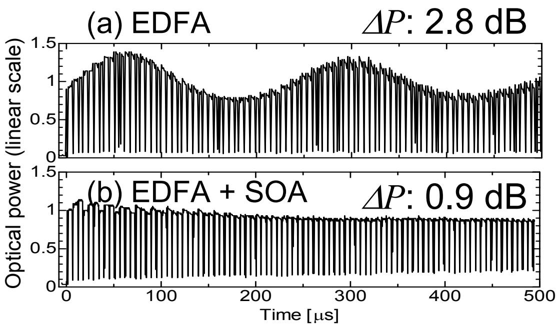

Figure 3. Optical power waveform from the fiber loop.

3. Fiber loop with EDFA followed by SOA

In order to suppress the relaxation oscillation, a low polarization dependent SOA module followed the EDFA in the fiber loop as shown in Fig. 1(b). In this experiment, the injection current of the SOA was a constant value of 100 mA. Then, the small signal gain and noise figure of the SOA module were 8.7 dB and 10.1 dB, respectively. The SOA saturation output power was 5.6 dBm. A variable optical attenuator (ATT) was inserted between each optical amplifier to change the operating point of optical amplifiers. Optical loss of α_1 is defined as the power loss from EDFA output to SOA input. α_2 represents the optical power loss from SOA output to EDFA input. In our setup, α_2 was 5.0 dB. Figure 3(b) shows the optical power waveform from the fiber loop with both EDFA and SOA. No relaxation oscillation is apparent in the case of (α_1, α_2) = (23.7 dB, 5.0 dB). Power variation at the top of the pulse was 0.9 dB in our measurement time range. This power difference is caused by the combination of signal frequency shift from AOS, EDFA gain tilt, ASE accumulation in EDFA saturation. Suppression of the relaxation oscillation can be explained by the gain saturation and fast response of the SOA [6].

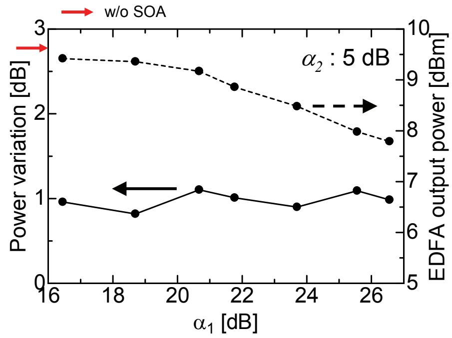

Figure 4. Optical power variation and output power with changing optical loss of α_1.

When the optical loss of α_1 is increased, then the SOA is more deeply saturated. Figure 4 shows the power variation of the fiber loop with changing the α_1. Almost identical power variation of 1 dB can be obtained with changing the SOA saturation. However, the output power tends to be small with low saturation. The pattern effect of SOA can be mitigated by using Manchester coding for signal.

4. Conclusion

Output power fluctuation of fiber loop buffer including a low noise EDFA can be suppressed by a following SOA. Because an EDFA is used as the first stage of the tandem configuration, the noise performance can be improved. In our system, optical amplifiers of the EDFA and SOA are driven by a constant current. No sophisticated control is needed for mitigation of power fluctuation.

References

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