40-Gb/s Optical Buffer Design and Simulation

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A photonic random access memory is important to enable buffering of high-speed optical packets in a transparent optical packet switched network. This paper proposes a new approach to create optical random access memory for 40-Gb/s optical telecommunications and presents the results of simulations to investigate the maximum achievable delay. The design combines silica waveguides for low loss recirculation with InP-based semiconductor devices for high gain and fast switching. This approach provides smaller devices in comparison to fiber-based alternatives and lower loss recirculation than competing material systems.

Figure 1 presents a diagram of the simulated integrated silicon and InGaAsP optical buffer. The proposed silica delay line is 210 cm long corresponding to a temporal length of 10 ns. An optical band pass filter is integrated into the model to reduce noise accumulation. The output signal for each circulation was obtained using the following analysis. The nonlinear Schrödinger equation was solved using a split-step-Fourier method to account for the signal propagation in the silica waveguide. The signal was multiplied by the gain function of the SOA, and then the amplified spontaneous emission (ASE) noise was added. Finally, the transfer function of the band pass filter was multiplied with the signal to yield the output signal for each circulation. The ASE noise was assumed to be white noise and was randomly generated for each circulation. The input signal was a 40-Gb/s return-to-zero (RZ) signal transmitted at 1550 nm and was modeled as a super Gaussian function with a pulse width of 12.5 ps. The total temporal length of the bit pattern was 6400 ps sampled with 16384 points, thereby accounting for a total bandwidth of 2.56 THz (20 nm). An ideal receiver was assumed and the Q parameter was calculated based on the Gaussian approximation.

The simulation investigated the maximum achievable delays to guarantee a bit-error-rate of 10^{-9} while accounting for performance limiting factors. Figure 2 shows the dependence of the number of round trips on the gain of the SOA. The figure demonstrates that the performance is limited by the ASE noise when the amplifier gain is lower than the roundtrip loss, while it is significantly degraded due to the amplifier saturation at the high gain above the roundtrip loss. Consequently there exists an optimum gain which is slightly higher than the roundtrip loss [1]. For each case the output power reaches a steady state value determined by the saturation output power of the SOA after several circulations [2]. Another result is the signal degradation due to the existence of small reflections at the facets of the SOA. In Figure 3 the maximum number of circulations around the optimum gain is shown to be reduced because of the accumulated gain distortion. In addition the amount of distortion depends on the amplifier gain itself and the relative position between the ripples and the signal wavelength [2]. Figure 4 shows the maximum delay versus input power and the coupling loss between the silica and InP waveguides. It is apparent that when the coupling loss is small, higher performance is obtainable with low input power and moderate amplifier gain. These simulations show that this approach should achieve buffer delays up to 100 ns and it is critical to design and fabricate the SOA with high saturation power and low reflectivity at the facets of the SOA and interfaces.

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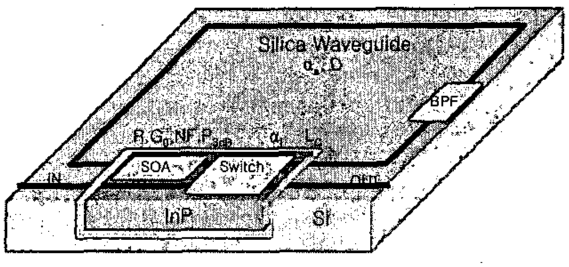
[3] M. Z. Iqbal, K. B. Ma, C. E. Zah, T. P. Lee, and N. K. Cheung, "Effects of Gain Ripples in Semiconductor Optical Amplifiers on Very High Speed Lightwave Systems," IEEE Phot. Techn. Lett., vol. 2, No. 1, pp. 48-50, Jan. 1990.



Silica waveguide	α_s: 0.05 dB/cm, length of 210 cm D: 5ps/km-nm
SOA	NF: 7 dB
Gain/Switch chip	α_i: 5 dB/cm, length of 1 cm
BPF	Gaussian-shape filter function with 2 nm bandwidth

Fig. 1. Schematic view of the optical buffer. (Silica waveguide) α_s: propagation loss, D: dispersion parameter, (SOA) G_0: unsaturated gain, NF: noise figure, P_{3dB}: output saturation power, R: reflectivity at the facets (Gain/Switch chip) α_i: propagation loss, L_C: coupling loss

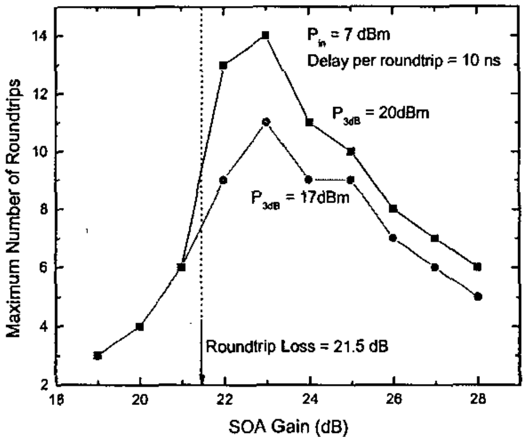


Fig. 2. Maximum delay versus the gain and the output saturation power of the SOA. L_C=3dB and R=0.

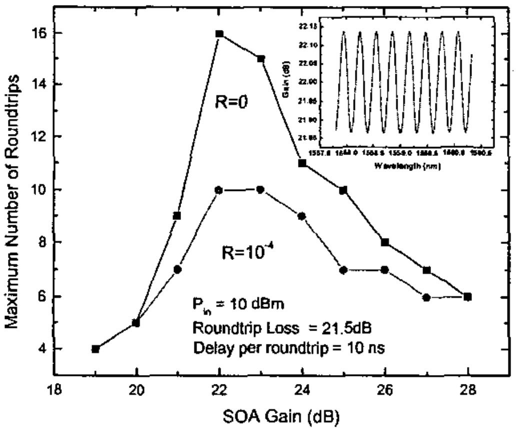


Fig. 3. Maximum delay versus the reflectivity of the SOA facets. (Inset) gain ripple for 1000 μm long SOA, 0.27dB gain ripple @R=10^{-4}

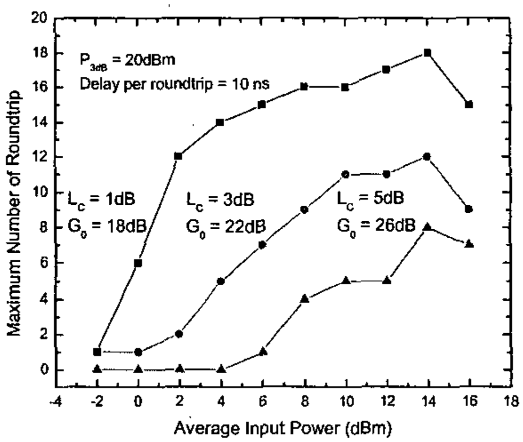


Fig. 4. Maximum delay versus coupling loss (L_C) and input power. Total loss per roundtrip: 17.5 dB @L_C=1 dB, 21.5 dB @L_C=3 dB, and 25.5 dB @L_C=5 dB.