40 Gbit/s transmission in a silicon-compatible $Al_2O_3:Er^{3+}$ integrated optical amplifier

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Erbium-doped waveguide amplifiers (EDWAs) are of interest for their potential use in integrated photonic circuits. Unlike semiconductor optical amplifiers (SOAs), which are typically fabricated using costly III-V materials and are limited in their capacity to amplify WDM signals (< 20 Gbit/s per channel) due to transient carrier effects [1], EDWA fabrication and design is straightforward, they can be processed directly on silicon, and their all-optical operation and long excited-state lifetime mean that amplification at high data rates is feasible [2]. Previously, transmission experiments at up to 10 Gbit/s have been reported using an EDWA [3]. In this paper we present the results of amplification of a 40-Gbit/s optical signal using an EDWA.

A sputter-deposited Er-doped aluminum oxide straight channel waveguide amplifier was fabricated on a thermally-oxidized silicon substrate. The device consists of a 5.4-cm-long $Al_2O_3:Er^{3+}$ ridge waveguide with an etch depth of approximately 70 nm and cross-sectional dimensions of 1 μm × 4 μm. The waveguide supports single-mode propagation at signal and pump wavelengths. Net internal small-signal gain of up to 9.3 dB was measured at a signal wavelength of 1532 nm, for 80 mW of launched pump power at 977 nm.

Transmission experiments were performed at a bit rate of 40 Gbit/s. Signal light from a tunable laser diode was sent through a pulse shaper with 20 GHz electrical clock followed by a coder to obtain the pseudo-random 40 Gbit/s non-return-to-zero (NRZ) bit sequence. The signal was then sent through an EDFA followed by a 3-nm filter to boost the signal and reduce amplified spontaneous emission from the EDFA. An optical attenuator then controlled the amount of signal power coupled to the device. The signal light and 1480-nm pump light from a Raman pump laser source were combined by a fiber wavelength division multiplexer (WDM) and coupled to the chip via a lensed fiber. At the output of the chip light was again coupled from a lensed fiber and through a 3-nm filter to eliminate transmitted pump light. The remaining signal was then coupled to a pre-amplifier, followed by an attenuator to control the amount of light coupled to the receiver. Light at the receiver was demultiplexed into 4 × 10 Gbit/s channels and coupled to a bit error rate (BER) analyzer.

Typical eye diagrams with and without the EDWA and lensed fibers are shown in Fig. 1 (a) for a 1532-nm signal. In both cases the eye pattern is open and no significant distortion can be observed with the EDWA included in the transmission setup. No difference in internal net gain was observed for the 40-Gbit/s encoded signal and a continuous-wave signal. The BER was measured as a function of received optical power with and without the EDWA by adjusting the optical power at the attenuator in front of the photodiode, see Fig. 1 (b). Compared to the reference signal, without EDWA and lensed fibers, for a pump power of 220 mW and a signal power of -0.5 dBm coupled into the device, only a small power penalty of approximately 1 dB is observed.

In conclusion, 40-Gbit/s data transmission has been observed in a silicon-compatible $Al_2O_3:Er^{3+}$ amplifier.

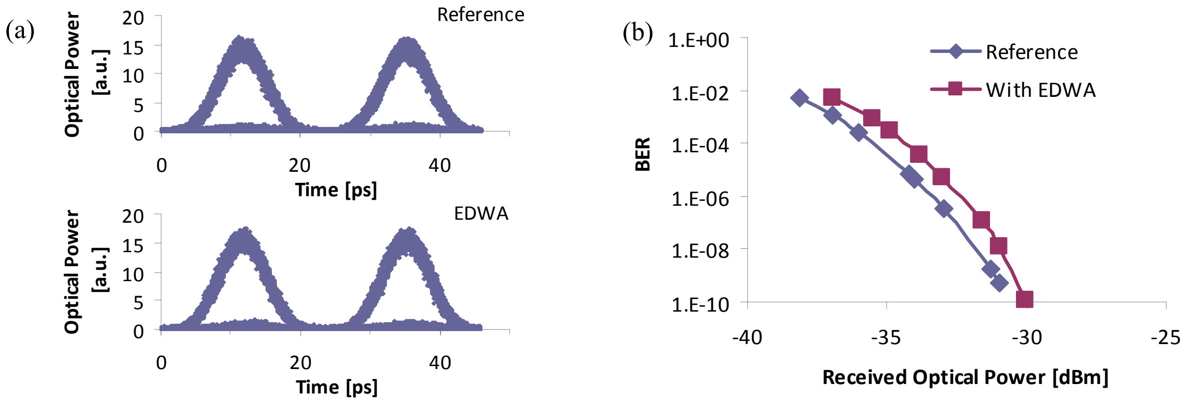

Fig. 1 (a) Eye diagram for system transmission experiment at 40 Gbit/s with and without EDWA; (b) bit error rate curve with and without EDWA included in setup.

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