1550-nm Vertical-Cavity SOAs for Optically Preamplified High Bit rate Receivers

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Abstract: *We report on optical preamplification using a 1550-nm vertical-cavity semiconductor optical amplifier (VCSOA). –28.5 dB receiver sensitivity was achieved at 10 Gb/s. The performance of the VCSOA at 20 and 40 Gb/s is evaluated.*

Introduction

Highly sensitive, high bit rate receivers are key components in optical communication systems. Optical preamplification is an attractive technique to reach high sensitivity at bit rates where avalanche photodetectors (APDs) are limited by their gain-bandwidth product. The best reported receiver sensitivity at 10 Gb/s is –29.5 dBm for an APD [1] compared to –38.8 dBm for an optically preamplified receiver that used EDFAs [2], and –32.4 dBm using semiconductor optical amplifiers (SOAs) [3]. At higher bit rates this advantage is even more pronounced.

Vertical-cavity semiconductor optical amplifiers (VCSOAs) are an interesting alternative to conventional amplifier technologies, especially for preamplifier applications. The vertical-cavity geometry results in polarization independent gain and high coupling efficiency to optical fiber, which is critical for low noise operation. It enables monolithic integration with other surface-normal devices and fabrication of 2-dimensional arrays. Furthermore, vertical-cavity devices are compatible with low-cost fabrication and testing techniques. One very important characteristic of VCSOAs is their narrow gain bandwidth, which allows them to function as amplifying filters, thereby eliminating the need for an optical filter after the amplifier. Optical preamplification at 10 Gb/s has been demonstrated in the 1310-nm wavelength range [4], but no VCSOA-preamplifier results have yet been presented for the important 1550-nm wavelength range.

Preamplifier experiment

An optically pumped 1550-nm VCSOA operated in reflection mode was used in the experiments. Details about the device structure can be found in [5]. A schematic of the experimental setup is shown in Figure 1. The VCSOA was pumped by a 980-nm diode laser. A 1550-nm tunable laser was used as a signal source. The signal was modulated using a $LiNbO_3$ Mach-Zehnder modulator and coupled into the VCSOA using a fiber and a lens. The input and output signals were separated by means of an optical circulator. The output signal from the VCSOA was fed to a Nortel PP-10G receiver followed by a broadband electrical amplifier. No optical filter was used after the VCSOA.

The receiver sensitivity was measured with and without the VCSOA preamplifier. The VCSOA was pumped at 80 mW pump power producing 13 dB of fiber-to-fiber gain and 32 GHz optical bandwidth. A 10 Gb/s 2^{23}-1 non-return-to-zero (NRZ) pseudorandom bit sequence (PRBS) was transmitted through the VCSOA, and received power versus bit error rate (BER) was measured. The results are shown in Figure 2. Without optical preamplification the receiver sensitivity corresponding to BER of 10^{-9} was –18.8 dBm. Using the VCSOA, the receiver sensitivity was improved by 9.7 dB resulting in -28.5 dBm sensitivity. The eye pattern at BER = 10^{-9} is also shown in Figure 2.

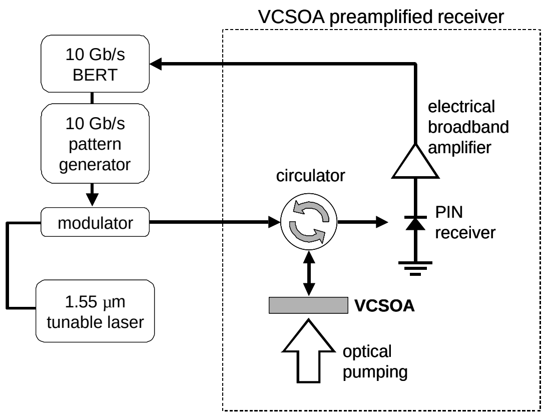

Figure 1. Experimental setup for VCSOA preamplifier experiment at 10 Gb/s.

Preamplification at higher bit rates was not possible because of bandwidth limitations in the receiver and the BERT. However, by using an electroabsorption modulator (EAM) to optically demultiplex the signal it was possible to determine the power penalty imposed by the VCSOA at 20 Gb/s. In order for the VCSOA to function at this bit rate it was necessary to decrease the gain and thereby broaden the gain bandwidth. The VCSOA was operated at 6 dB of gain with a gain bandwidth of 120 GHz. The power penalty at 20 Gb/s was measured to be 4.7 dB. At 40 Gb/s an error floor was observed at BER = 10^{-10} resulting from a strong pattern dependence at this bit rate. Eye patterns at 20 and 40 Gb/s are shown in Figure 3.

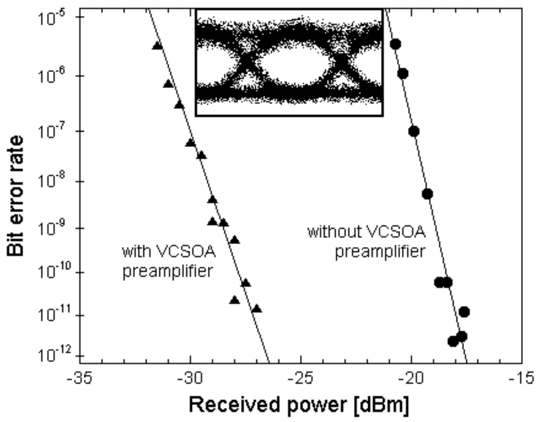

Figure 2. BER versus received power at 10 Gb/s with and without the VCSOA. The eye pattern after the VCSOA at BER = 10^{-9} is also shown.

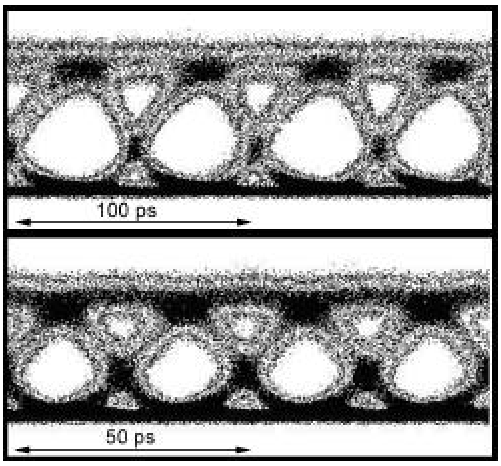

Figure 3. Eye patterns at 20 Gb/s (top) and 40 Gb/s (bottom) after VCSOA operating at 6 dB of fiber-to-fiber gain.

Tunable VCSOAs

For many applications, a narrow-band amplifying filter with a fixed center wavelength is of limited use. In CWDM systems for instance, the specs for the transmitter wavelength is fairly loose and all components in the system must tolerate variations in signal wavelength due to temperature variations. Furthermore, tunable receivers are very attractive for channel selection in broadcast-and-select systems. It is therefore of great interest to make tunable VCSOAs that can cover a wide wavelength range and at the same time be very precisely adjusted to a specific wavelength.

We have fabricated tunable VCSOAs by integrating a microelectromechanical (MEMS) structure with a VCSOA. In this design, the top DBR is replaced by a DBR on a suspended membrane. Tuning is achieved by applying a reverse voltage across a *p-i-n* diode in the membrane supports, which creates an electrostatic force that pulls the DBR closer to the active region of the device. Details about the design and fabrication of these devices can be found in [6]. 11 nm of tuning with 10 dB of gain (not including coupling loss) has been obtained. Figure 4 shows gain spectra at different tuning voltages.

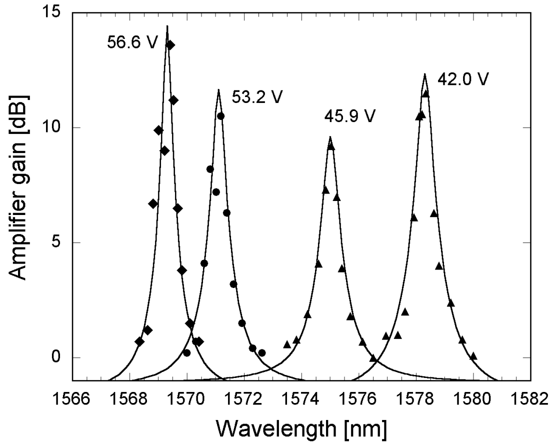

Figure 4. Gain spectrum of tunable VCSOA at different tuning voltages.

Summary

We have presented optical preamplification at 10 Gb/s using a VCSOA. The receiver sensitivity of a regular *p-i-n* receiver was improved by 9.7 dB, resulting in a sensitivity of –28.5 dBm. Tunable VCSOAs are promising devices for the realization of compact, low-cost, tunable, high-speed receivers.

References

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