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Influence of RZ and NRZ signal format on the high-speed performance of gain-clamped semiconductor optical amplifiers

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1. Introduction

Semiconductor optical amplifiers (SOAs) are attractive as gates for future all-optical switch blocks since they feature the high on-off ratios of 40-50 dB that are needed to overcome the severe penalty induced by crosstalk. At the same time they provide 20-30 dB gain and thereby compensate for losses in the switch block. However, an important issue in conventional SOAs is extinction ratio degradation due to gain saturation at high input powers, which has a severe impact on the cascadability of such gates. Therefore, gain-clamped SOAs [1] (GC-SOAs) have attracted much interest since they exhibit high saturation input powers resulting in superior cascadability for both single and multi-wavelength systems [2,3]. Still, at bit rates of 10 Gbit/s and beyond the performance of GC-SOAs is limited due to the influence from the limited relaxation frequency causing pulse pattern distortions [4], which become more severe as the bit rate is increased. Consequently, the cascadability of GC-SOAs is considerably reduced at high bit rates. For future high-speed systems fabrication of GC-SOAs with high relaxation frequencies is therefore essential. However, this has not been accomplished so far. In this paper we experimentally show that the influence of a limited relaxation frequency of the GC-is reduced by using a RZ (Return-to-Zero) signal format instead of a NRZ (Non-Return-to-Zero) signal format. Experiments show that as a result of this, a higher input power dynamic range (IPDR) is achieved at 20 Gbit/s using RZ signals compared to NRZ signals at 15 Gbit/s.

2. Device description

The GC-SOA used in the experiments has a total length of 1000 μm. This is divided into a 600 μm long active region that is placed between two passive Bragg regions, each with a length of 200 μm. The device has a lasing wavelength of 1508 nm with a threshold bias current of ~50 mA. It has an unsaturated chip gain of 21 dB and a high saturation input power of ~−10 dBm at 200 mA. Furthermore, the relaxation frequency of the GC-SOA is 13-14 GHz. The structure of the device is described in more detail in [5].

3. Experimental set-up

In Fig. 1 is shown the experimental set-up for characterization of the GC-SOA using RZ (Fig. 1.a) and NRZ input signals (Fig. 1.b). As indicated in Fig. 1.a, the 20 Gbit/s RZ-signal is generated in the following way: Short pulses (~16 ps) are generated at a wavelength of 1550 nm by a gain-switched DFB-laser, whereupon the pulse train is externally modulated by a $LiNbO_3$ modulator at 10 Gbit/s and passively multiplexed to 20 Gbit/s. As seen in Fig. 1.b, the 15 Gbit/s NRZ signal having a wavelength of 1555 nm is generated by electrical multiplexing of a 7.5 Gbit/s signal. The 15 Gbit/s optical signal is then obtained by externally modulating a CW laser. In both cases a PRBS length of 2^7-1 is used. The filter at the output of the GC-SOA is employed to filter out the lasing signal from the GC-SOA. In the pre-amplified receiver the signals are demultiplexed before detection and BER measurements. The demultiplexing of the RZ signal is performed by using a $LiNbO_3$ modulator, while the NRZ signal is demultiplexed electrically. It is noted that there is no difference in the performance of the GC-SOA at 1550 nm and 1555 nm since both gain and noise figure are approximately the same at the two wavelengths.

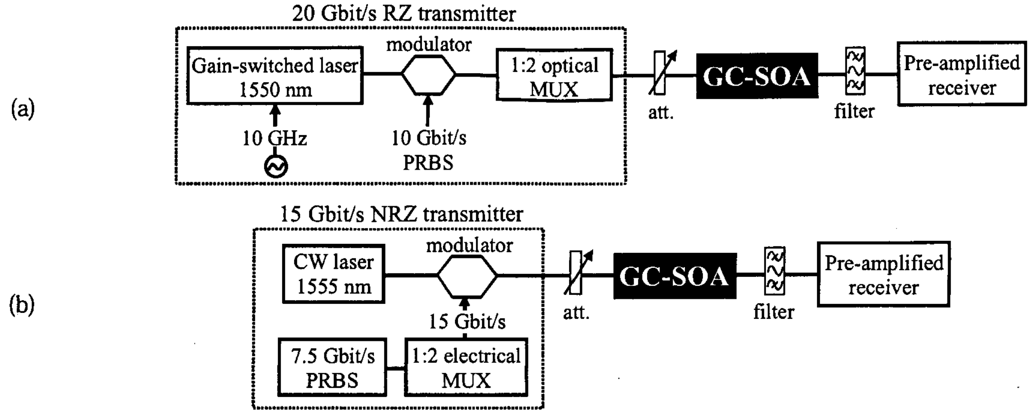

Fig. 1. Schematic of experimental set-ups for assessment of BER performance of GC-SOA. (a) 20 Gbit/s RZ experiments at 1550 nm. (b) 15 Gbit/s NRZ experiments at 1555 nm.

4. Results

Fig. 2 shows the measured receiver penalty as a function of the signal input power to the GC-SOA for both the 20 Gbit/s RZ signal and the 15 Gbit/s NRZ signal. In both cases the penalty at low input powers to the gate is caused by a low signal-to-noise ratio. However, as seen in Fig. 2, the performance is best when the NRZ signal is employed. This is mainly due to a lower electrical bandwidth of the receiver when using the 15 Gbit/s NRZ signal compared to the 20 Gbit/s RZ signal, resulting in less beat noise in the receiver. The penalty at high input power

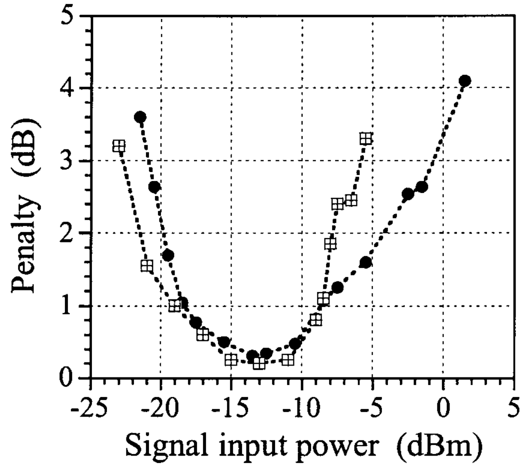

Fig. 2. Measured receiver penalty as function of the signal input power to the GC-SOA. Circles indicate results for a 20 Gbit/s RZ data signal, while squares indicate results for a 15 Gbit/s NRZ data signal. The bias current to the gate is 200 mA.

levels is caused by extinction ratio degradation due to gain saturation and pulse distortion resulting from the limited relaxation frequency. Fig. 2 indicates that at high input power levels a superior performance is attained when using the RZ signal, i.e., a 4 dB higher input power can be tolerated at penalty of 2 dB. This format-dependent performance can be explained as follows: In contrary to the NRZ signal, marks occurring in the RZ signal are not affected by the limited relaxation frequency due to the short pulse width. This is confirmed in Fig. 3, showing the measured pulse traces of the 20 Gbit/s RZ signal (Fig. 3.a) and the 15 Gbit/s NRZ signal (Fig. 3.b) at the output of the GC-SOA. The input powers to the GC-SOA are -1 dBm and -7 dBm in the two cases, respectively. As seen in Fig. 3.b, the output NRZ signal has experienced pattern effects on both marks and spaces, whereas the RZ signal only has distortions on the spaces even though the input power is ~6 dB higher and the bit rate is 5 Gbit/s higher.

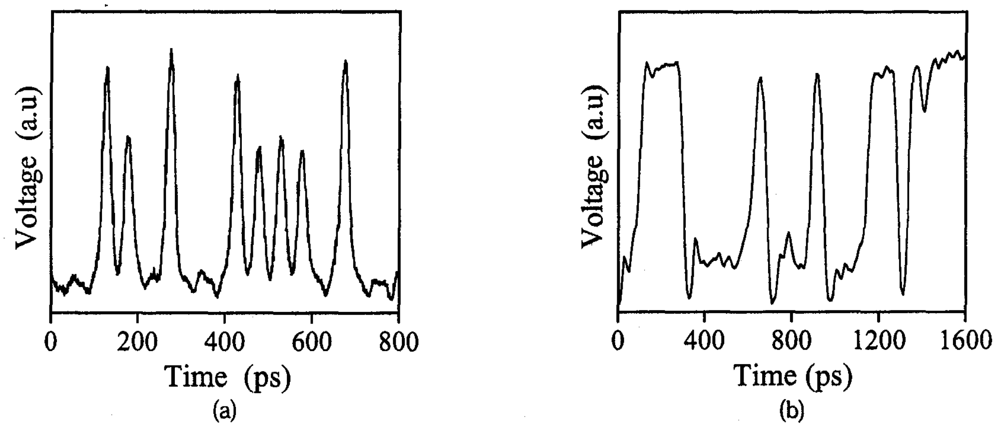

Fig. 3. Measured pulse traces at the output of the GC-SOA for (a) 20 Gbit/s RZ input data signal having power of -1dBm. (b) 15 Gbit/s NRZ input data signal having a power of -7dBm. The bias current to the device is 200 mA.

5. Conclusion

The input power dynamic range of a GC-SOA has been measured using a 20 Gbit/s RZ and a 15 Gbit/s NRZ signal format. Experiments clearly show that the influence from the limited relaxation frequency of GC-SOAs, which severely degrades the performance at high bit rates for NRZ signals, to some degree can be avoided by using RZ signals. Hereby, it was shown that a 4 dB higher input power can be tolerated (@ 2 dB penalty) with a 20 Gbit/s RZ signal compared to a 15 Gbit/s NRZ signal even though the bit rate is 5 Gbit/s higher.

6. References

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