All-optical 2R Regenerator and Decision Gates by Gain-Clamped SOA's in a Mach-Zehnder Configuration

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Introduction

All-optical regeneration will be essential in future high-speed optical systems to suppress accumulation of noise and jitter, which severely limit the network node cascadability. Several techniques for all-optical regeneration have been investigated, and some of the most promising results have been achieved with interferometric wavelength converters (IWCs) [1, 2]. In these devices, 2R regeneration is accomplished due to the nonlinear transfer function of the converter [3]. However, the amplitude imbalance decreases the extinction ratio of the interferometer. Very recently, improved regeneration was proposed utilizing an interferometric structure incorporating gain-clamped SOAs (GC SOAs) as phase shifters [4].

The gain saturation induced non-linearity generates crosstalk which is a severe limitation for the use of SOAs in WDM based systems. In contrast, GCSOA has a gain that is constant with respect to input power variation, as long as the amplified signal power is less than the oscillating power, leading to a flat gain versus output power response. The coupling with the lasing mode also results in a readjustment in carrier density by relaxation oscillations.

In this paper, we report a GC SOA structure with two integrated Bragg gratings as wavelength selective reflectors. By incorporating the GC SOA's into a MZI structure an all-optical decision gate is thus constructed. The device structure to be simulated is schematically shown on Fig. 1. The GC SOA's need to be traveling-wave amplifiers in this case. It is a 3-section device that consists of a central gain section and two passive sections. Each passive section includes a distributed grating reflector so as to form a DBR cavity. The length is 200 ? m for the passive sections, 400 ? m for the active section. The coupling coefficient (?) of the grating will affect the extent of gain coupling. We chose a ? ? L value leading to around 11 dB gain at 1550 nm.

Simulation Results:

The simulations have been performed using a commercial software package [5], which uses powerful and flexible laser models based on the Transmission-Line Laser Model (TLLM) [6]. The parameters used in the simulation are summarized in Table I.

Table I. GC SOA parameters used in the numerical simulations.

Parameter	***Value***	***Unit***
Active region width	2.5? 10^{-6}	m
Internal loss	3000	m^{-1}
MQW confinement factor	0.07	---
SCH confinement factor	0.56	---
Bimolecular recombination coefficient	1.0? 10^{-16}	m^3/s
Auger recombination coefficient	1.3? 10^{-41}	m^6/s
Linear material gain coefficient	3? 10^{-20}	m^2
Transparency carrier density	1.5? 10^{+24}	m^{-3}
Carrier capture time constant	70? 10^{-12}	s
Carrier escape time constant	140? 10^{-12}	s

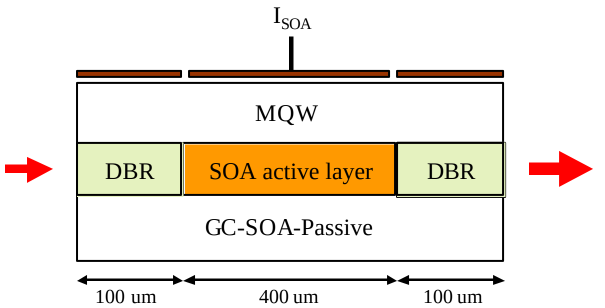

Fig. 1. Schematic view of the DBR GC SOA.

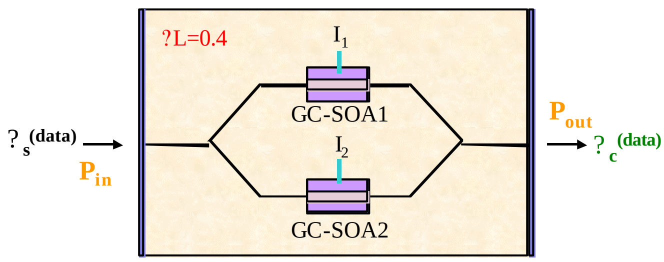

Fig. 2. Schematic view of an optical decision gate.

The light-versus-current curve shows threshold oscillation around 30 mA and maximum power output 27 mW per facet at 200 mA. The optical spectrum above the threshold current shows ASE peak close to 1550 nm as well as oscillating wavelength of 1530 nm. The gain curves with respect to the driving current are reported in Fig. 3 and show a practical gain curve of about 11 dB. The gain curve with respect to the signal output power is reported in Fig. 4. A flat gain is observed up to 17 dBm output power.

To examine the suppression of gain saturation, eye diagrams for 10 Gbit/s PRBS data sequence with 1 mW input power are shown in Fig. 5 for SOA and GC SOA cases. In contrast to the degraded signal in SOA case, the GC SOA gives a better output waveform due to the improved carrier dynamic response.

The structure of the MZI-based reshaping, with symmetric couplers and identical GC SOA's in both arms, is shown in Fig. 2. The GC SOA's are assumed to be completely identical and to have a different bias current. They, therefore, give an identical and constant amplification and phase shift below the saturation power, but they exhibit a different saturation power. Calculated characteristics of 2 GC SOA's with different bias are shown in Fig. 6. As can be seen from the figure, the transfer function for this regeneration scheme is close to that of a decision gate. The turning points of regeneration characteristic depend on the bias current I_1 and I_2 of the two GC SOAs. Changing one or both of the bias currents would allow the adjustment of the decision threshold and/or the slope of the decision characteristic. This is illustrated in Fig. 6, in which the decision characteristics for various values of I_1 clearly exhibit a different slope.

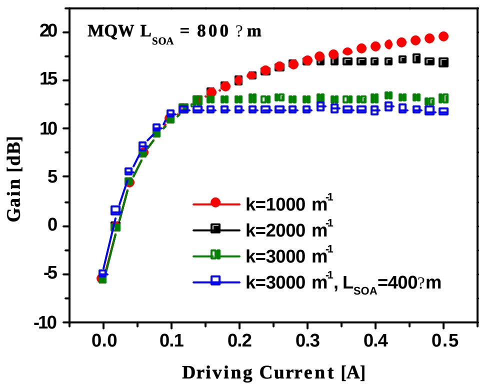

Fig. 3. Gain versus current of DBR GC SOA at 1550 nm.

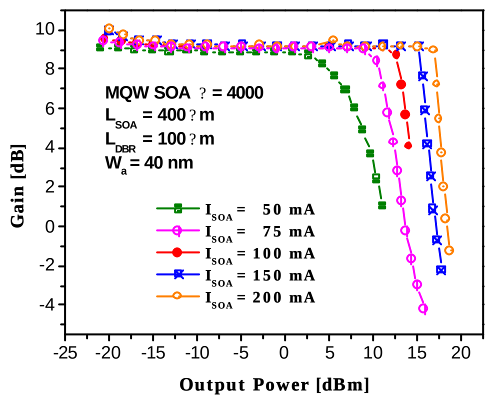

Fig. 4. Gain versus output power of DBR GC SOA.

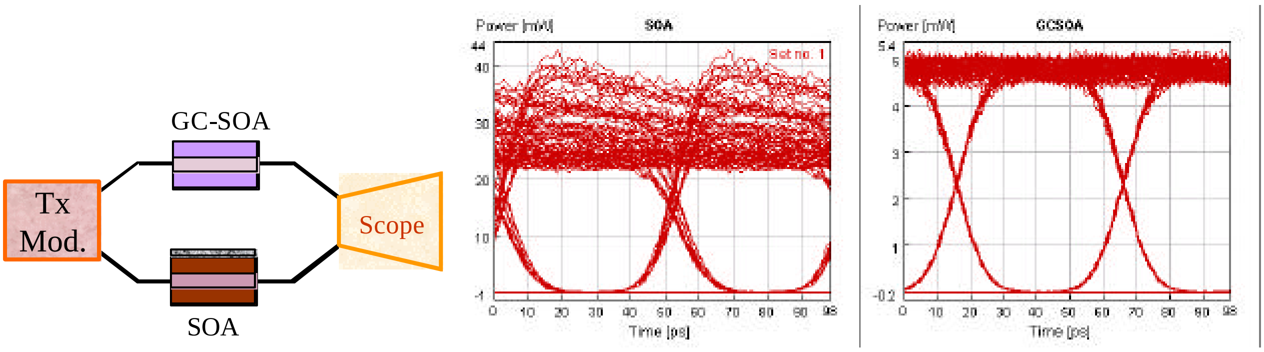

Fig. 5. Eye diagrams after the SOA and GC SOA. Note that the GC SOA exhibits the reshaping effect.

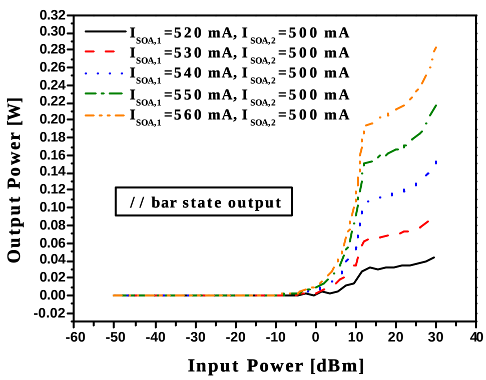

Fig. 6. Output power versus input power of a decision gate for various I_1.

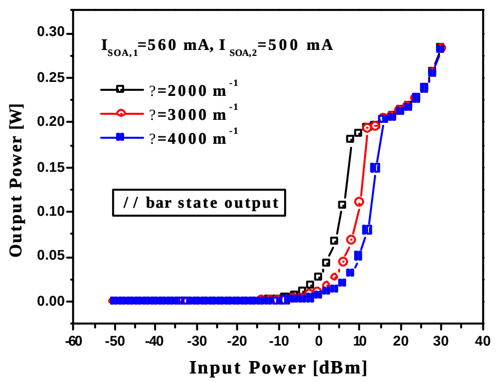

Fig. 7. Output power versus input power of a decision gate. for various kappa value.

To obtain a larger adjustable decision threshold we also tried the simulations by varying the ? ? L value in GC SOA's. It can be clearly seen in Fig. 7 that about 10 mW threshold downshift can be attained through the decrease of ? from 4000 to 2000 m^{-1}. The decreased decision threshold is mainly resulted from the reduced reflectivity when forming the DBR grating with a smaller ?.

Conclusions

An all-optical decision gate based on MZI configuration incorporating GC SOA's is proposed to implement the 2R regeneration for future high-speed optical systems. By varying the bias currents of one or both GC SOA's, we can adjust the gate decision threshold and decision characteristic. Optimizing the laser design parameters such as ? value provides us another solution to improve the output gain and gate decision threshold.

References

[1] Chiaroni, D. Lavigne, B., Jourdan, A., Hamon, L., Janz, C., and Renaud, M., Proc. ECOC'97, Edinburgh, UK, 1997, Vol. 5, pp. 41-44.

[2] Lavigne, B., Chinroni, D., Hamon, L., Janz, C., and Jourdan, A., Tech. Dig. OFC'98, San Jose, USA, 1998, Paper Th07.

[3] Wolfson, D., Mikkelsen, B., Danielsen, S. L., Poulsen, H. N., Hansen, P. B., and Stubkjaer, K.E., Tech. Dig. OFC'98, San Jose, USA, 1998, Paper WB3.

[4] Morthier, G., Gyselings, T. and Beats, R., Tech. Dig. OFC'98, San Jose, USA, 1998, Paper WM19.

[5] **VPI**transmission**Maker**™ **Active Photonics** simulation suite.

[6] Lowery, A.; Lenzmann, O.; Koltchanov, I.; Moosburger, R.; Freund, R.; Richter, A.; Georgi, S.; Breuer, D.; Hamster, H. Selected Topics in Quantum Electronics, IEEE Journal on, Volume: 6 2000, Page(s): 282 –296.