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Analysis of Optical Logic Gates Based on SOA

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ABSTRACT: Optical packet networks topic has drawn to itself wonderful concern within the last few years. A lot of efforts have been addressed to deal with all those issues derived from the use of optical packets to carry the information. In this dissertation we focused on the XOR logic gate implementation, because it is a very versatile approach for implementing many functions in optical communication networks. We develop and study of a novel architecture based on SOA-MZIs to perform the logic XOR operation between two input binary sequences. The experimental implementation and operation arguments of the optical XOR logic gate at 10 Gbit/s. Header processing is one of the principal functionalities required at intermediate nodes, where a packet must be routed to the corresponding premises.

Keywords: SOA (Semiconductor optical amplifiers), MZI (Mach-Zehnder interferometer),

I. INTRODUCTION

Within today's Internet, data is transported between powerful electronic Internet protocol (IP) routers using optical-fibre transmission and wavelength-division-multiplexing (WDM) systems. Fibre-transmission systems today typically carry tens of wavelengths modulated at rates beyond 1 Gbit/s. In an IP router, multiple WDM fibres are terminated and signals are converted from the optical to the electronic domain at the input and from electronic to optical at the output [**1**]. Today's routers need to handle in excess of 1 Tbit/s of data in order to redirect incoming Internet packets from fully loaded WDM fibres. When comparing the increase of optical fibres capacity with the speed of electronic processor, it arises that there is a potential mismatch in bandwidth handling capability between fibre-transmission systems and electronic routers [**2**]. This situation could become more complicated if we consider that future routers will terminate potentially hundreds or thousands of optical wavelengths and the increase in bit rate per wavelength will head out to 40 Gbit/s and potentially beyond [**3**]. Electronic processing in this scenario would not be able to handle the routing of a massive number of packets per second, which could easily lead to router congestion. Or at least, not a reasonable cost. From an economic perspective, conversions between optical and electrical formats at the inputs and outputs of a router can grow to be half of the cost of a node, and even more, electronics working at high bit rates would show up a problem of power consumption and heat dissipation [**4**]. The aim of this paper is the proposal, study, and validation of all-optical logic gates architectures, based on SOA-MZIs.

This topic has attracted very interest in the literature in the last years, as can be inferred from the huge number of publications in this field.

II. OPTICAL LOGIC GATESBASED ON SOA-MZI

Within the optical communications field, interferometric-based wavelength-converters have been broadly deployed and used. Among other advantages, these devices may act as signal regenerators, with low optical signal levels needed to achieve the necessary phase shift between the interferometer arms, leading to a very efficient operation. Furthermore, interferometers based on the use of SOAs have turned out to be a main building block for the development of all-optical regenerators and simple signal-processing elements [8]. The SOA-MZI is a highly versatile element not only due to the large number of feasible applications, but also because most of the Boolean logic operations can be implemented with the same architecture. The SOA-MZI is a device with several input/output ports on each side. The ports are bidirectional in the sense that the same port can be used as an input port or an output port. This is due to the bidirectional operation of the SOAs. The interferometer is comprised of two branches in which a SOA is placed. In a basic operation the SOA acts as a nonlinear element, inducing an additional phase change on one of the signals propagating through it. This phase change is caused by another signal that can be co-or counter-propagating through the same SOA. From now on, the different configurations to achieve the logic Boolean functions and the specific use of each input/output port of the SOA-MZI will be analysed [9-11].

III. SOA BASED ON XOR GATE

The XOR gate has a special interest since it is the main building block for a wide range of functions. Due to its compactness and stable structure, SOA-MZI based XOR gate seems an easy solution to achieve the integration level required for complex logic circuits [4-6]. Basically, this Boolean function gives a logic “1” if the two inputs that are being compared are different (combinations A = 1, B = 0, and A = 0, B = 1). On the other hand, if the inputs are the same (combinations A = 1, B = 1, and A = 0, B = 0), the XOR output signal is a logic “0”. In the case of optical gates, the logic “1” is represented by the presence of an optical pulse, whereas the logic “0” means absence of optical power.

IV. WORKING PRINCIPLE OF XOR GATE

In the cases in which A = 0, B = 0, the control pulse enters the SOA-MZI at port 3, and then is split into two pulses, one reaching the upper SOA, and the other reaching the lower one. At this point, due to the phase shift induced at the input coupler, the phases of the two versions of the control pulse are shifted $\pi/2$. The SOAs are under the same conditions, as no data pulse has arrived to neither of them, so the phase shift is still $\pi/2$. These two pulses, after passing through the SOAs, are recombined again at the output coupler were they suffer again an additional $\pi/2$ phase shift between them. So at the output port the two pulses are with the same amplitude and with a total phase shift of π, i.e. destructive interference, and no signal is obtained. In the case A = 1, B = 0, an optical pulse enters the SOA-MZI through port 1 and changes the refractive index of the upper branch SOA whereas the lower SOA remains unaffected. Thus, when the two versions of the control pulse travel through both SOAs, the phase difference between both is shifted (π is the optimum phase shift). At port 4, the signals (parts of the control signal) from the two SOAs are combined again and an optical pulse is obtained as a consequence of the constructive interference (note that the optical coupler imposes an additional π phase shift between the input signals, so the total phase shift is 2π). The same phenomenon happens if A = 0 and B = 1. In the case A = 1, B = 1 (see Figure 1(a, b)), data pulses reach both SOAs, and the phase shift induced to the control pulse in each branch is the same. As a result, at port 4 no pulse is obtained in this case due to destructive interference between the signals pulses.

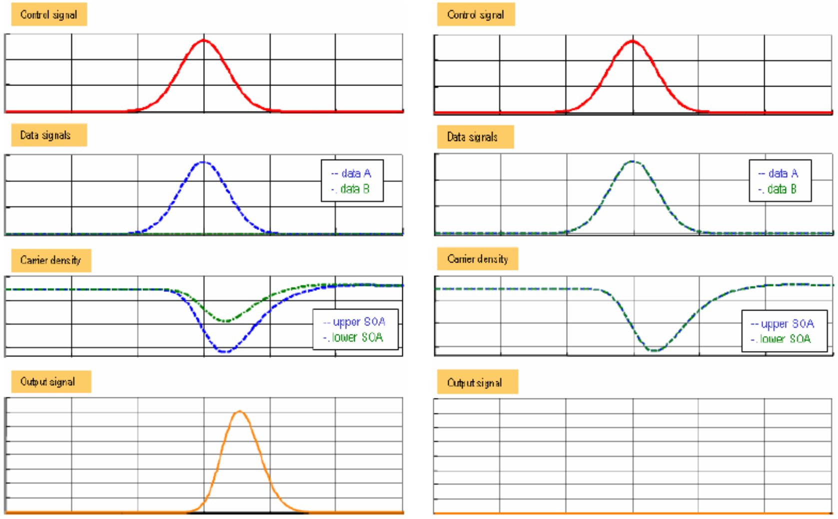

Fig. 1. Detail of the signals involved in (a) constructive interference and (b) destructive interference. The control and data signals are depicted. The carrier density of both SOAs and the output pulse are also showed.

V. XOR GATE EXPERIMENTAL SETUP

In the cases in which A = 0, B = 0, the control pulse enters the SOA-MZI at port 3, and then is split into two pulses, one reaching the upper SOA, and the other reaching the lower one. At this point, due to the phase shift induced at the input coupler, the phases of the two versions of the control pulse are shifted π /2. The SOAs are under the same conditions, as no data pulse has arrived to neither of them, so the phase shift is still π /2. These two pulses, after passing through the SOAs, are recombined again at the output coupler were they suffer again an additional π /2. phase shift between them. So at the output port the two pulses are with the same amplitude and with a total phase shift of π , i.e. destructive interference, and no signal is obtained which is shown in Fig. 2.

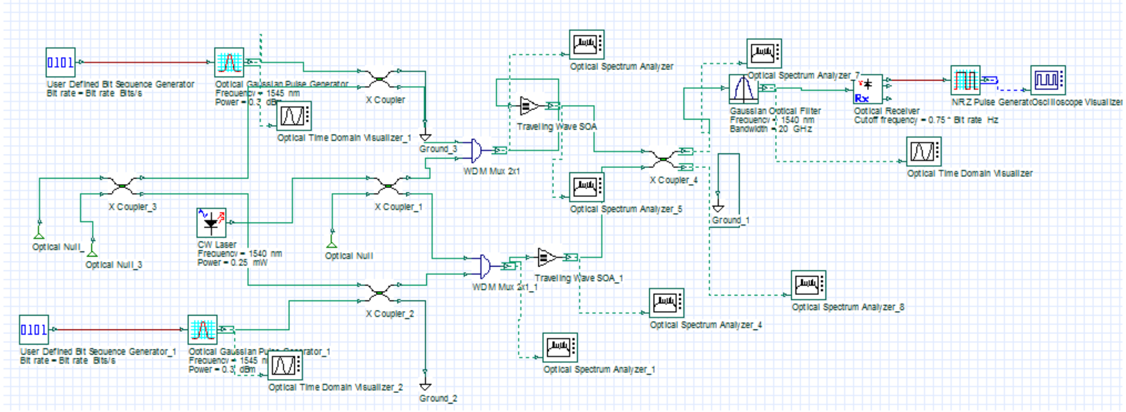

Fig. 2. Experimental setup of SAO-MZI based XOR gate.

In the case A = 1, B = 0, an optical pulse enters the SOA-MZI through port 1 and changes the refractive index of the upper branch SOA whereas the lower SOA remains unaffected. Thus, when the two versions of the control pulse travel through both SOAs, the phase difference between both is shifted (π is the optimum phase shift). At port 4, the signals (parts of the control signal) from the two SOAs are combined again and an optical pulse is obtained as a consequence of the constructive interference (note that the optical coupler imposes an additional ð phase shift between the input signals, so the total phase shift is 2 π). The same phenomenon happens if A=0 and B=1. In the case A=1, B=1, data pulses reach both SOAs, and the phase shift induced to the control pulse in each branch is the same. As a result, at port 4 no pulse is obtained in this case due to destructive interference between the signals pulses.

VI. RESULT & DISCUSSION

The setup consists of a laser source emitting CW light at a wavelength of 1540 nm. The CW light is passed through a coupler & multiplexer, before its injection onto the SOA. SOA biased current is fixed at 300 mA. A minimum power of – 30dBm is initiated and gradually increased up to 0 dBm. The SOA's gain saturation is plotted in Figure. 3from the graph; SOA gain is nearly linear in the range of -30dBm to 0 dBm. The gain of SOA decreases due to carrier density of SOA decreases with increasing the input power.

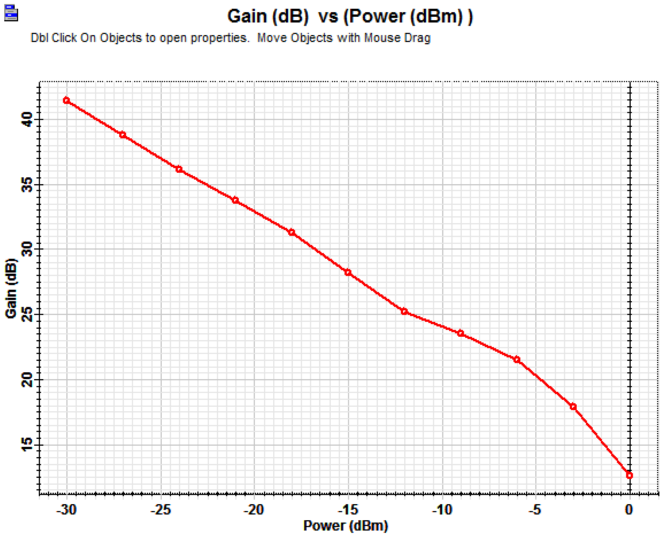

Fig. 3. SOA gain saturation for increasing of input power.

VII. CONCLUSION

Simulation as well as experimental results show the suitability of the SOA-MZI based architecture to perform different logic functionalities of XOR logic operations. These configurations show a very good stability on power level fluctuations of the input signals, data as well as control signals, and on synchronisation issues. The Boolean functionalities have been successfully demonstrated using low energy levels and without any additional pump signal.

REFERENCES

[1] NurIzzatibt Ab Rahman, Mohamad Halim Abd. Wahid Characterization of OR Logic Gate Based on SOA-NOLM *Symposium on wireless technology and application IEEE* 2013 pp, 40-43.

[2] M. Nady, Khlid Hussain, Abd-EI-Hadi Ultrafast All Optical Gate Quantum-Dot Semiconductor Optical Amplifier-Based MZI *31th National RadoiSience Conference in Egypt.*

[3] Saurabh Kotiyal, Himanshu Thapliyal and Nagarajan Ranganathan Mach-Zehnder Interferometer Based All Optical Reversible NOR Gates 2012 *IEEE Computer Society Annual Symposium on VLSI* pp.no-207-212.

[4] G.K. Maity, S.P. Maity and J.N. Roy Design of All-Optical New Gate Using Mach-Zehnder Interferometer *IEEE* 2013 pp.no. 445-450.

[5] Aihan Yin, Li Li, Xinliang Zhang. "Analysis of 2.5 Gbit/s GPONdownlink optical receiver performance." 2008: 198.

[6] Huining Han, Min Zhang, Peida Ye, Fangdi Zhang. "Parameter design and performance analysis of an ultrafast all-optical XOR gate based on quantum dot semiconductor optical amplifiers in nonlinear mach–zehnder interferometer." *Optics Communications,* **281**, 2008: 5140-51145.

[7] H.J. Lee, C.S. Park, *IEICCE Trans. Commun.* **E84B** (2001) 330.

[8] Francis T. S. Yu, Suganda Jutamulia, Shizhuo Yin. *Introduction toinformation optics.* Academic Press, 2001.

[9] S. Diez, E. Hiliger, M., C. Schmidt, C. Schubert, H.G. Weber, L. Occhi, L. Scharees, G. Guekos, L.K. Oxenloewe. "Optimization of SOA-based Sagnac-interferometer switches for demultiplexing to 10 and 40 Gb/s."*Optics Communications* **189**, 2001: 241-249.

[10] K.L. Deng, I. Glesk, K.I. Kang, and P.R. Prucnal, *Unbalanced TOAD for optical data and clock separation in self-clocked transparent OTDM networks*, *IEEE Photonics Technology Letters*, 1997, vol. **9**: pp.830-832

[11] M. Eiselt, W. Pieper, H.G. Weber, SLALOM:semiconductor laser amplifier in a loop mirror, *J. Lightwave Technol.* **13**(10) (1995) 2099–2112.

[12] K.I. Kang, T.G. Chang, I. Glesk, P.R. Prucnal, Comparisonof Sagnac and Mach–Zehnder ultrafast all-optical interferometric switches based on a semiconductor.

[13] J.Q. Li, L. Li, L. Lin, C.F. Li, All-optical switch and limiter based on nonlinear polarization in Mach–Zehnder interferometer coupled with a polarization maintaining fiber ring resonator, *Opt. Commun.* **260** (2006) 318–323.