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Design Aand Analysis Of High Speed Optical Logic XOR Gate Using SOA-MZI Structures

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Abstract— Optical computation plays the major role in enhancing the speed, data transmission rate and processing power by replacing the electronic circuits with the optical circuits. All optical circuits are very efficient for high speed signal processing by performing digital computations through photons instead of electrons. This paper reviews the different technology of all-optical circuits in all optical processing from the basics to advanced logic gates to the extent of recent implementation in all optical signal processing. Various schemes in optical processing are discussed, compared and the future direction is outlined.

Keywords: Mach-Zehnder interferometer (MZI), semiconductor optical amplifier (SOA), all-optical logic gate, XOR.

I. INTRODUCTION

All-optical logic gates become key elements in the realization of node functionalities, as add drop multiplexing, packet synchronization, clock recovery, address recognition, and signal processing. Semiconductor optical amplifiers (SOAs) are very attractive nonlinear elements for the realization of different logic functions, since they can exhibit a strong change of the refractive index together with high gain. Moreover, different from fibre devices, SOAs allow photonic integration. The nonlinear behavior that is a drawback for the SOA as a linear amplifier makes it a good choice for an optically controlled optical gate [1]. Gates with better performance are achieved by placing SOAs in inter-ferometric configurations. In these gates, the optical input signal controls the phase difference between the interferometer arms through the relation between the carrier density and the refractive index in the SOAs by means of cross-phase modulation (XPM) [2]. These inter-ferometric SOA-based configurations are compact and offer stability.

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Moreover, different from fibre devices, SOAs allow photonic integration. In the following section theory of SOA is well presented. In the subsequent sections principle of operation, simulation step and experimental result of AND Gate, OR Gate, XOR Gate are presented, respectively. In the last section, conclusion of paper is presented.

Previous Work AND THEORY

Signal regeneration is an intrinsic and very attractive feature of such devices. Mach-Zehnder nterferometer (MZI) have been widely used to implement optical logic gates.

The XOR, AND and OR operation are performed up to 10 Gbit/s using MZI configuration [3-6].

In order to realize the logical gates, various configurations of optical logic gates have been reported that utilize the ultrafast non-linear properties of SOA's, including from single SOA structure using cross gain modulation(XGM) to inter-ferometic structures, such as terahertz optical asymmetric de-multiplexer (TOAD) and ultrafast nonlinear interferometer (UNI), etc. These schemes have been shown to have some advantages, but they are difficult to control or construct and polarization states or random phase changes are critical for their output performance. Among them, SOA-MZI structure using XPM is the most promising candidate due to its attractive features of low energy requirement, simplicity, compactness by integration, capability, and stability. In addition, it has the merits of high ER, regenerative capability, high speed operation, and low chirp. So far, all-optical AND and XOR gates using SOA-MZI structure have been investigated. The all-optical AND gate is one of the fundamental logic gates because it is able to perform the bit-level functions such asaddress recognition, packet-header modification, and data-integrity verification. The all-optical XOR gate is a key technology to implement primary systems for binary address and header recognition, binary addition and counting, decision and comparison, encoding and encryption, and pattern matching. This gate has been demonstrated at 10 Gb/s In this paper, we propose and experimentally demonstrate all-optical composite logic gates with XOR, AND and OR functions using SOA-MZI structure at 10 Gb/s. The proposed design is optimized by adjusting the optical power and biasing current in SOA-MZI structures to obtain output pulses with maximum ER.

Logic Gates Based on Nonlinearities on SOAs:

The effect that makes the SOA a very interesting device for application in optical networks is the so called nonlinear effects that have been characterized are: XPM and XGM.

Cross Gain Modulation:

The XGM effects consist on the variation of the SOA gain in function of the input power. The increase of the power of the input signal causes in the SOA a depletion of the carrier density, and therefore, the amplification gain is reduced. The dynamics processes that take place in the carrier density of the SOA are very fast of the order of picoseconds, so it is possible to use this variation on the gain with bit to bit fluctuation of the input signal power.

Cross Phase Modulation:

In fact, this later effect is the principle of operation of the XPM. The variation on the carrier density induces a change on the refractive-index, and so the phase of the continuous wave is modulated.

This phase modulation can be converted in intensity modulation by using MZI configuration.

II. IMPLEMENTATION OF SOA-MZI BASED XOR GATE

The XOR gate has a special interest since it is the main building block for a wide range of function [7-9]. Basically, the Boolean function gives the logic "1" if the two inputs that are being compared are different (combination A=1, B=0, and A=0, B=1). On the other hand, if the inputs are same (combination A=1, B=1, and A=0, B=0), the XOR output signal is a logic "0". In the case of optical logic gates, the logic "1" is represented by the presence of an optical pulse, whereas the logic "0" means absence of optical power.

Principle of Operation

To perform the XOR Boolean function two optical beam carried by the optical signal at the same or different wavelengths are sent through the port 1 and port 2 of the MZI separately. The wavelength of the two data signal can also be the same. A train of pulse or CW beam is coupled to port 3 as the control signal. The control signal splits into two equal parts, one reaching the upper branch of the interferometer and the other reaching the lower branch. When data signal (bit sequence to be compared) is launched into the SOAs, the carrier density and thereby, the medium refractive index is modulated. This causes the phase shift over the control signal counter propagating through the SOAs (control signal) according to the intensity variation of the input data signals [10-12]. This phase modulation experienced by the wave during propagation in the SOA is given by:

$$\Delta\emptyset = 2\emptyset\pi n_0 \frac{L}{\lambda} + \propto [\ln(G) + \ln(G_0)]$$

Being λ the wavelength of the input data signal passing through the SOA, α the SOA line width enhancement factor, n the refractived index in the absence of the optical power, G the saturated gain and G0 is the linear device gain. This equation is obtained from the analytical models of wavelength converters under certain condition such as the instantaneous response of the SOA and the adiabetic approximation.

The XOR gate, gives a "1" at the output if one, and only one of the two inputs is a "1". More generally, an XOR gate with an arbitrary number of the input gives a "1" at the output if the parity of the input bits is "1", i.e., the number of "1" is odd. This property of the XOR gate makes it suitable for a wide variety of applications related to bit-comparison and encryption.

III. PROPOSED METHODOLOGY

In the case 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 phase shift induced at the input coupler, the phases of the two versions of the control pulses are shifted π /2. The SOAs are under the same condition, as no data 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 where 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, hence destructive interference, and no signal is obtained (Figure 2). In case A=1, B=0 an optical pulses enters the SOA-MZI through port 1 and changes the refractive index of the upper SOA whereas the lower SOA remains unaffected. Thus, when the two versions of the control pulses travels through the both SOAs, the phase difference between both is shifted (π is the optimum phase shift). At port 4, the signals (part of the control signal) from the two SOAs are combined again and an optical pulse is obtained as consequence of the constructive interference. The same phenomena happens if In the case of data pulses each 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 signal pulses.

In this simulation we have generated two data signal as shown in Figures 3(a) and 3 (b). The SOA-MZI setup is used to perform XOR operation. These two data signals are generated at 1545 nm wavelength with the help of optical Gaussian pulse generator. A continuous wave is also generated at 1540 nm. These signals are given to the SOA-MZI ports for performing XOR operation (Figure 3(c)) between the two data signals applied at port 1 and port 2 of SOA-MZI setup.

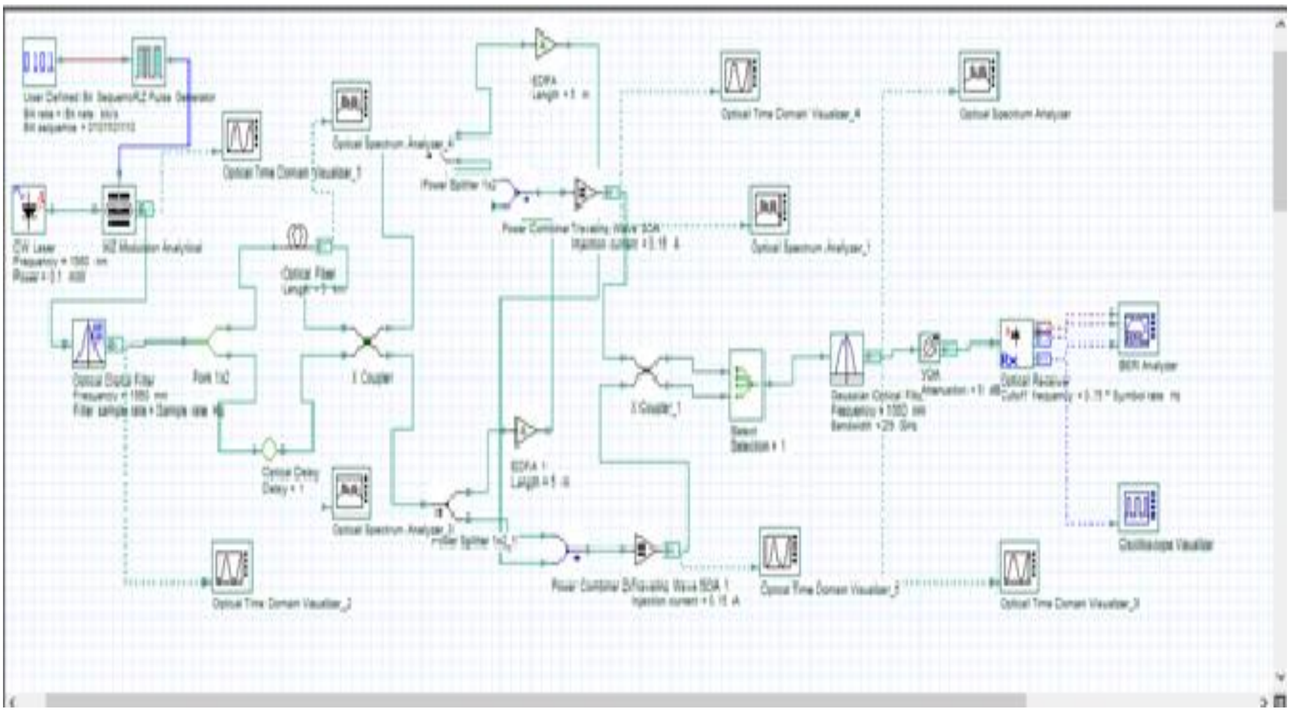

Fig4.1:Experimental Setup for XOR Gate on OptiWave Simulation

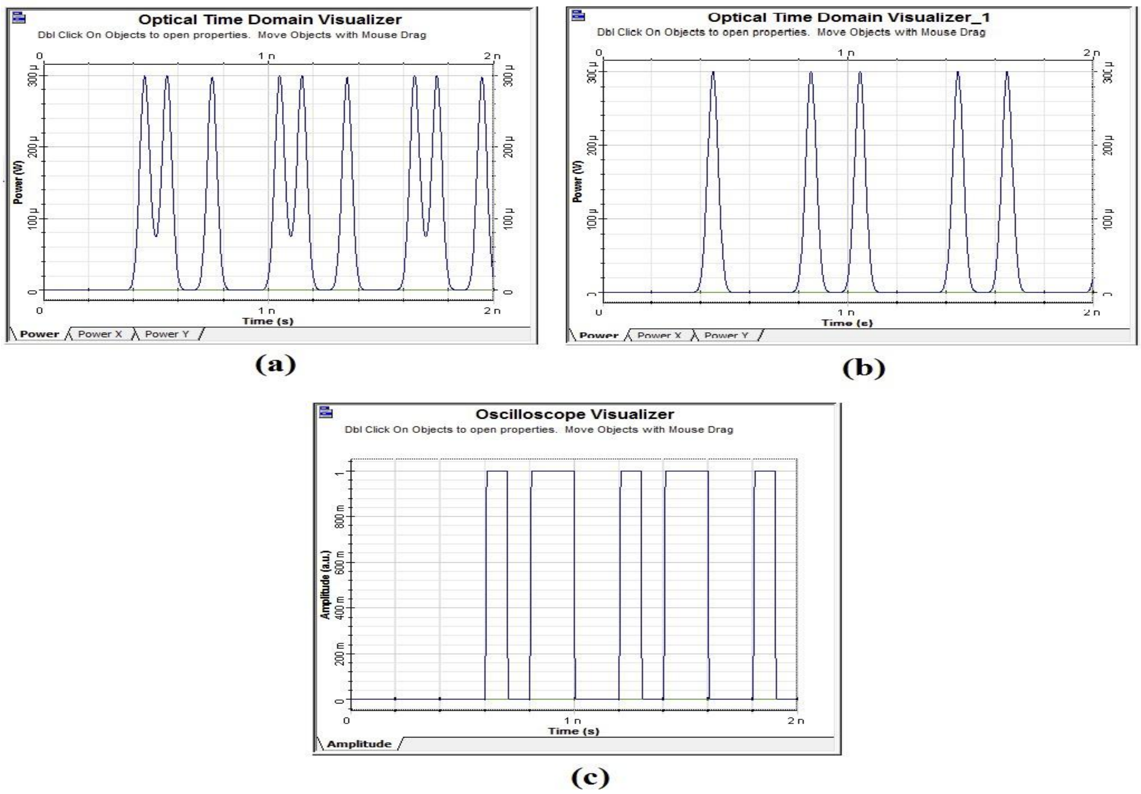

Fig 4.2: Input and output waveforms

IV. SIMULATION/EXPERIMENTAL RESULTS

In this simulation We have discuss XOR gate Implementation. Injection current for Travelling Wave SOA is 0.15Amp.One CW laser is used to generate the input signal. This CW laser is tuned at frequency 1560nm and the power is 40mw. One signal from the same delay will be delayed using optical delay. The input an d the delayed version of the input are applied to the optical coupler.

In this simulation we have generated one data signal. The SOA-MZI setup is used to perform XOR generated at The input probe signal modulated by the CW laser source at 1560nm with power 0.1mw.The delayed signal is generated from the same laser signal at 1560nm with the optimum delay of 800ps for this logic.

The input and delayed signals are applied to an optical coupler in the RZ format. The outputs of the optical coupler are applied to two SOAs with directly coupled and cross coupled after erbium doped amplifier (EDFA) amplifications. When both input and delayed signals have binary "1," the outputs of the optical coupler have peak amplitude ass compared to any other binary digit. When these signals are combined at output, due to opposite phase variations with time of the both delayed and input signals, there is cancellation of binary "1" digit.

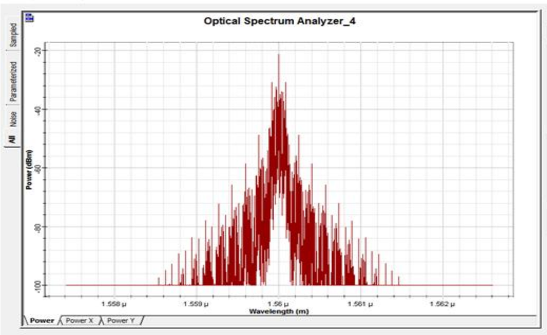

Fig 5.1: Input Signal

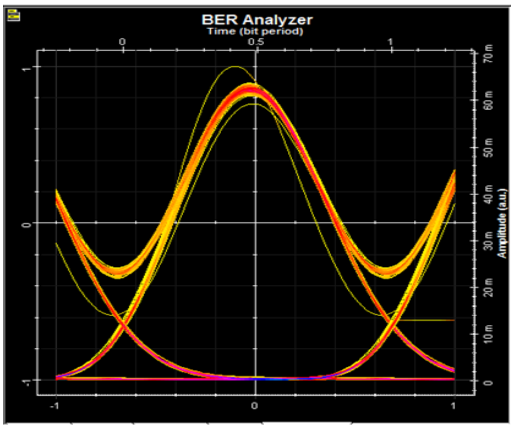

Fig 5.2 : Eye Diagram of the resultant XOR Logic

The clear eye diagram is observed as in fig. 5 with the quality of signal. Low output power XOR logic can be obtained after combining the input and delayed signals at adequate quality.

These results show improvement over the results of [9], [10] and [12] and good agreement with results of [11] in terms of bit rate.

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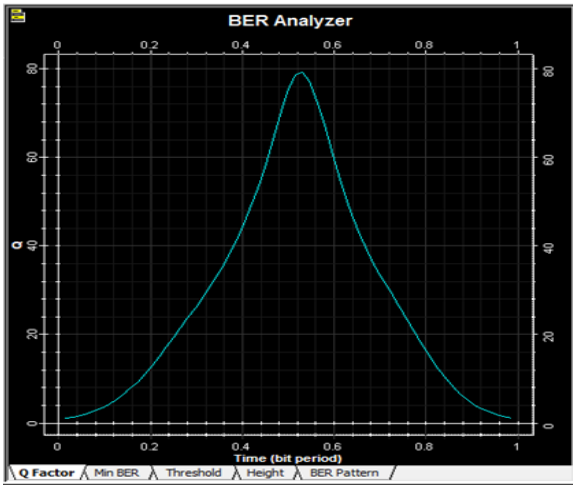

Fig 5.3: Q-Factor

V. CONCLUSION

Here, the SOA-MZI proposed structures also optimize the logic gate at 60Gb\s switch out using any additional circuitry along with efficient quality. This proposed setup is that the implementation of logic gates is done by using a single-wavelength source with the SOA-MZI configuration.

Due to its compactness and stable structure, SOA-MZI based gate seems an easy solution to achieve the integration level required for complex logic circuit.

VI. FUTURE SCOPES

The foreseen scenario for the next years seems to be changing very fast.It is accepted fact is that optical packet networks based on all-optical technologies are a very long term approach, more than 20 years. This long term delay forced the main funding resources for investigation in EU moving on to short term alternatives. These choices is consist on hybrid solutions, allowing to a more immediate application of the architectures for nodes in optical networks without substantial modifications on the equipment already installed.

Optical logic gates presented in this Thesis have been tested at the lab at a bit rate of 60Gbit/s and at 140Gb/s. As an immediate step forward operation at higher bit rates, experimental validation at 80 Gbit/s and 160 Gb/s will be carried out. It is envisaged that a differential scheme at the input of the gate will be required.

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