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IMPLEMENTATION OF ALL-OPTICAL AND & OR GATES USING SOA

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Abstract- As the need for higher bandwidths in high capacity networks is being endorsed, it is being forseen that at some point in the future digital processing will be performed all-optically. Several techniques have been postulated to perform such all-optical signal processing. Semiconductor Optical Amplifiers (SOA) is one such novel initiative in the upcoming all- optical networks. They are being very well used as wavelength converters, optical logic gates, bit comparators and in many other all-optical digital signal processing applications. In this paper, the design of an all-optical AND & OR gate using cross-gain modulation of semiconductor optical amplifiers has been suggested and demonstrated successfully at 10 Gb/s.
Keywords- Cross gain modulation (XGM), Semiconductor optical amplifier (SOA), optical gates, AND gate, OR gate, wavelength conversion.

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Introduction

As ever growing demand for bandwidth has been spurring the data rate per wavelength to approach the speed limit of electronics, all optical signal processing is expected to assist in releasing the network from undesirable latencies related to optical-electronic- optical (O/E/O) conversions at the switching nodes [1].

Optical gates are key devices for realization of many functionalities in optical networks and optical computing. Due to their potential applications, all-optical logic gates have received considerable attention in the field of optical networks [2]; they can enable many advanced functions such as all-optical bit pattern recognition [3], all -optical bit-error rate monitoring [4], all-optical packet address and payload separation [5], all-optical packet drop in optical time domain multiplexing (OTDM) networks [6] and all-optical label swapping [7].

All-optical logic device can be classified into several types such as the nonlinearity based on fibers, wavelength conversion based on a semiconductor optical amplifier. Compared with their optical fiber based counterparts, all optical logic gates based on semiconductor optical amplifiers are promising because of their power efficiency and their potential for photonic integration [8-2].

Of all the available techniques, SOAs not only provide the gating operation but they can be used for fair amplification and efficient wavelength conversion [4].The flexibility of SOAs is attributed to its non-linear behavior such as Four wave mixing (FWM), Cross gain modulation (XGM) and Cross phase modulation (XPM).

The XGM characteristics are elementary to implement and have delivered sound results at ultra-high bit rates. Also, they exhibit high conversion efficiency and polarization independence to input signals [5].

Although, SOA based all-optical gates have been proposed, designed and demonstrated successfully in the previous works available in literature, but the design being presented in this paper offers attractive features over other postulated designs. The attractiveness of this design eventually leads to simpler structure and cost reduction. most of the approaches using SOA use multiple SOA structures in different topologies. The schemes that have been made use of are co-propagating and counter-propagating

structures. However, this novel design requires the use of only one SOA as cross gain modulation ability of SOA has been put to use.
Moreover, the cross gain modulation (XGM) has been the principle behind the proposed design of all-optical gates. This non-linear property of SOA is polarization independent which means the design will not require any polarization controllers, polarisers and polarization mode-fibers (PMF). This further simplifies the design and reduces the system cost.
The need of optical delay lines (as required in previous works) has been eliminated. Optical delay lines were required as the data given to both the data inputs was same, the difference being the delay provided to 1st data stream to generate 2nd data stream. Now, in this design, the user of the all-optical gates has been provided with the choice to give customized data to both the data signals. This is accomplished by giving the Pseudo random bit sequence (PRBS) generators a customized file of input data.
All these advantages show a marked improvement over other designs in terms of system cost, complexity and high bit rate performance.
In this paper, a successful realization of all-optical OR and AND gate has been accomplished at 10 Gb/s. Simulations have shown that higher bit rates upto 600 Gbps are also possible using the same setup. Other gates can also be realized using the same setup such as NAND gate as demonstrated in paper [12].

Operation Principle

An SOA is an opto-electronic device which can amplify an input light signal. The active region inside the SOA provides gain to an input signal.
The desirable properties of SOAs include high gain and gain bandwidth, minimal facet reflectivities, low polarization dependence and high saturation power. The nonlinearities in SOAs include Cross gain modulation (XGM), Cross phase modulation (XPM) and Four-wave mixing (FWM).
The simplest application of XGM is shown in Fig. 1 where a weak probe light and a strong pump light, with a small signal harmonic modulation at angular frequency ω, are shot together into an SOA.

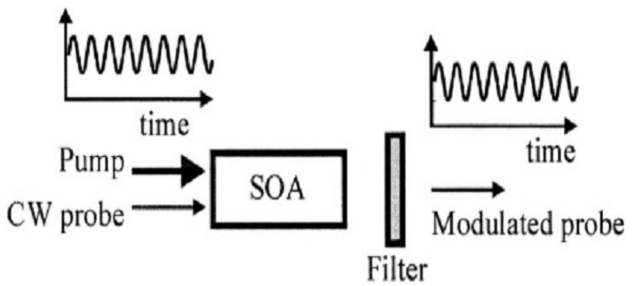

Fig. 1- Wavelength conversion in an SOA

XGM in the amplifier enforces the pump modulation on the probe. So, the amplifier acts as a wavelength converter as it places the information on one wavelength to another signal at some other wavelength.
Although, there are many SOA gate configurations possible, the most basic arrangement is shown in Fig. 2. The state of output is determined by the input optical control pulses at λ1 which when high establish the carrier density modulation due to spectral broadening of input signal at wavelength λ2. [11]

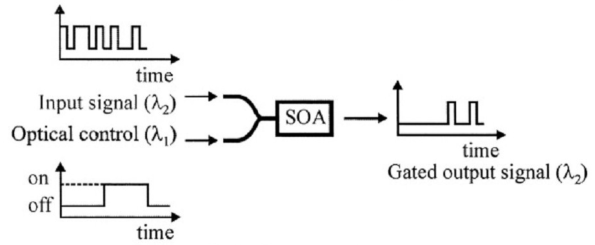

Fig. 2- A basic optically controlled SOA gate

Simulation Setup

The simulation for AND gate as shown in Fig. 3 was performed using OptSim 5.2 by RSoft a simulation based tool for designing advanced optical communication systems.
The data streams D1 at wavelength 1553.05 nm and D2 at wavelength 1557.75 nm were generated by modulating the mode-locked laser optical output by an electrical PRBS (pseudo random binary sequence) generator.
These two data streams namely Data1 and Data2 were then combined using a 3 dB coupler OptCoup1. In order to match the power levels of both the data streams, optical attenuators OptAtten1 and OptAtten2 were adjusted at 4.76 dB and 0.7 dB. To differentiate between identical data streams, a slight delay of 99 ms was incorporated using variable delay component FiberDelay1.
Also, a nonlinear fiber NLFiber1 of length 2000m was inserted into the second data stream to avoid dispersion effects at the final output.
The two different data streams were then recombined using an optical multiplexer OptMux2 followed by their amplification an EDFA black box amplifier EdfaBB1. An optical band pass filter OptFilt1 with centre wavelength at 1555.44 nm (the mean of the wavelengths of Data1 and Data2) was used to select only the required spectrum of the data streams.
The probe signal was also generated using a mode-locked laser tuned at wavelength 1548.3 nm and subsequently modulated by a PRBS generator. This probe signal along with combined data stream were simultaneously fed into the SOA using 3-dB coupler OptCoup2 followed by an optical multiplexer OptMux1.
Inside the SOA, cross gain modulation of carrier induced charges takes place in accordance with the changes in the data streams Data1 and Data2. An optical band pass filter centered at wavelength 1561.83 nm and bandwidth 0.5 nm selected the desired AND operation.
2. The simulation set-up for OR gate has been depicted in Fig. 4. The two data streams Data1 (wavelength 1557.75 nm) and Data2 (wavelength 1563.15 nm) were again generated using two different mode-locked lasers.
These optical pulses were then modulated using PRBS generators in both the data streams.
These two data streams Data1 and Data2 were then combined using an optical multiplexer OptMux1 and then amplified by an EDFA amplifier EdfaBB1
As was seen in the AND setup, a probe signal at wavelength 1548.3 nm was generated by another mode-locked laser and then

modulated by a PRBS generator.

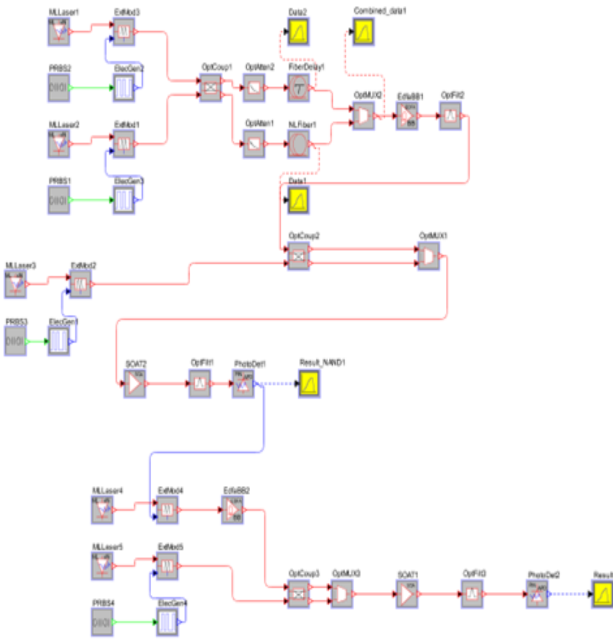

Fig. 3- Simulation Setup for All-optical AND gate

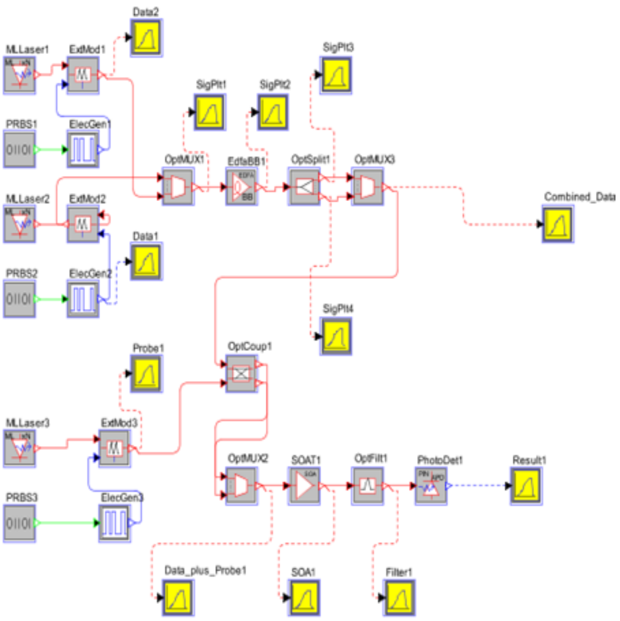

Fig. 4- Simulation Setup for All-optical OR gate

The probe along with the combined data stream (consisting of Data1 and Data2) were then introduced into the SOA cavity using a 3-dB optical coupler OptCoup1 followed by an optical multiplexer OptMux2.

Inside the SOA active region, cross gain modulation takes place in the probe carriers in accordance with the changes in the data streamsAt the SOA output, an optical band-pass filter OptFilt1 tuned at wavelength 1546.8 nm was placed to select the desired OR operation.

The input power levels of the data signals Data1 and Data2 and probe signal for both the gates are summarized in Table I.

Table 1- Input power levels of data and the probe

S. No.	Signal	Power Level
1	Data1	0.786 mW
2	Data2	0.965 mW
3	Probe Signal	0.55 mW

Results and Discussion

AND Operation

As in the AND logic, we have a logic high when both the data inputs are high. When one or both the pulses are low, we have a logic zero output.

In the simulation results it was observed that logic high pulses are obtained but they are time shifted. Moreover some residual pulses are obtained which should not appear in the ideal case. However results could be improved by optimizing the filter.

Table 2- Truth table for AND operation

Data1	Data2	Output
0	0	0
0	1	0
1	0	0
1	1	1

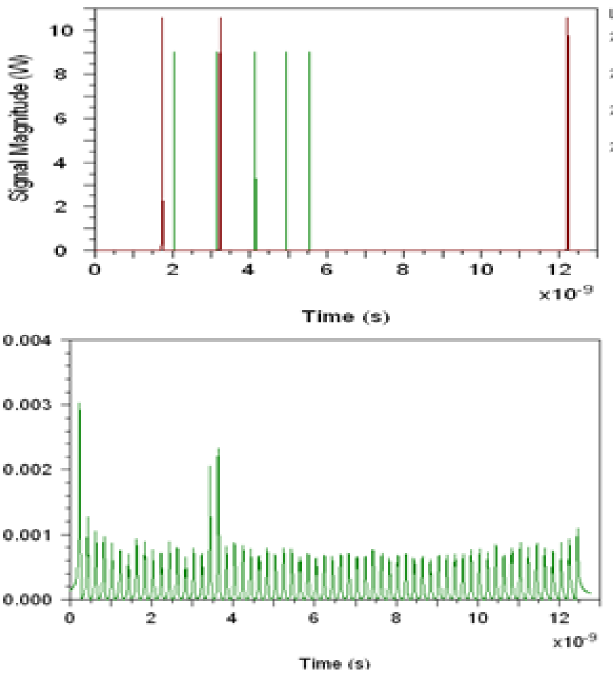

Fig. 5- Data Signals and corresponding results of All-optical AND gate setup

OR Operation

In the OR operation, the output is high only when one or both of the data inputs are at logic high. When both the inputs are low we have a logic low. In the results of OR operation shown in Fig. 6, whenever there is a logic high input (either Data1 or Data2), we have a logic high output. So, there is successful realization of all-optical AND & OR gates.

Table 3 -Truth table for OR operation

Data1	Data2	Output
0	0	0
0	1	1
1	0	1
1	1	1

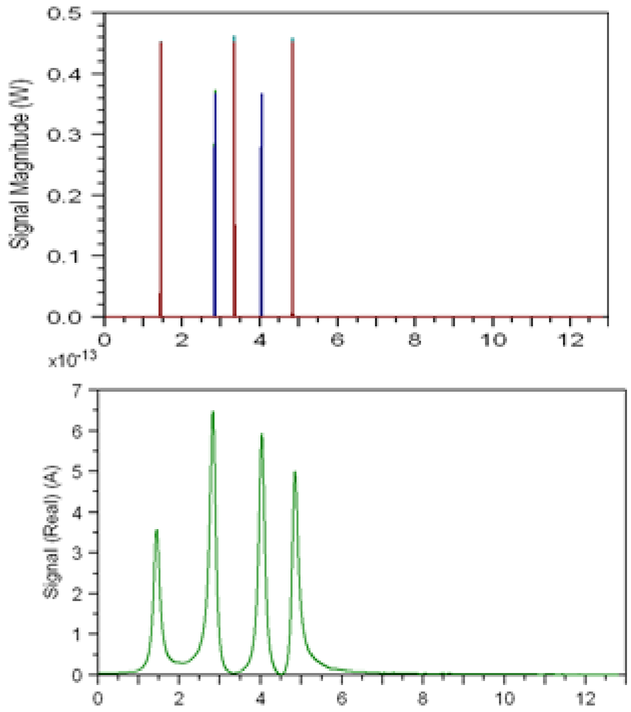

Fig. 6- Data Signals and corresponding results of All-optical OR gate setup

Conclusion

All optical AND & OR gates was demonstrated by exploiting XGM in SOA. Output signal versus input signal was investigated. The proposed set up for optical AND & OR gates is compact, simple and allows simple and stable operation at 10 Gbps.

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