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Design and Simulation of Optical Logic NOT and AND Gate Using SOA

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Abstract
All optical logic gates are the key elements in the realization of node functionalities.Moreover logic gates are capable of operating in optical domain because of its aspect of avoiding the need of optical-electronic-optical conversion.In this paper an optical logic NOR and AND gate is realized using single SOA.Logic gates arerealized using non linarites of semiconductor optical amplifiers which includes four wave mixing,cross gain modulation,XPM. Logic gate is implemented using RZ modulated signals at 40 Gb/s operational speed. Contrast ratio and extinction ratio values have also been analysed for logic gate.

Keywords
Cross phase modulation (XPM), cross polarization modulation (XPolM),Semiconductor Optical amplifier (SOA).

I. Introduction

Communication means sending of information from one place to another through a medium. There are many mediums which can be used for data transmission like twisted pair cable, coaxial cable system. But optical fibre is given high importance due to its huge capacity. Within last few days optical packet networks has drawn a good attention and now a days optical packets are used to carry the information. There is a growing demand forthe networks having large capacity and capability for transparent routing. Optical amplifiers have made possible a number of significantadvances in the optical networks. Light gets attenuated during propagation over long-distances in optical fibers. . Optical amplifiers are mainly utilized to amplify opticalsignals. Optical switching and wavelength conversion are also some of the importantapplications of these devices. There are two types of optical amplifiersi.e. OPTICAL FIBRE AMPLIFIRE and SEMICONDUCTOR AMPLIFIRE. Optical fiber amplifiers are used for in line amplification. SOA is very promising for the use in evolving optical fiber communication networks. This is due to the advances in the device design and optical semiconductor fabrication techniques.SOA can be used for amplifying optical signals and also have many functional applications.These include wavelength conversion, an optical switching, and regeneration, in line amplification and mid span spectral inversion. These are the main functions required in transparent optical networks. Transparent optical networks do not require any conversion of optical signals into the electrical domain and vice-versa.Polarization independence compact size, low power consumption and high speed are the salient features of this device.

II. SOA NON Linearities

SOA is very small in size andis pumped electrically. The difference between SOA and otherdoped fiber amplifiers is its way of achieving population inversion. The population in theSOA are carriers (i.e. electrons or holes) in a semiconductor material.
.Moreover this device is less expensive than the Erbium Doped Fiber Amplifier (EDFA) and can be integrated with modulators, semiconductor lasers, etc.. SOAs are sensitive to polarization. Waveguide structure and the gain material are some of the important factors responsible for these device applications. They have been used in many functional applications, including switching, wavelength conversion, power equalization, 3R regeneration, logic operations etc. The major aspect of SOA is its nonlinear effects, which has been discussed in this paper thoroughly. These effects are: the self-gain modulation (SGM), the self-phase modulation (SPM), the self-induced nonlinear polarization modulation (SPR), the cross-gain modulation (XGM), the cross-phase modulation (XPM), the four-wave mixing (FWM) and the cross-polarization modulation (XPolM).

A. Self Phase Modulation

The self-phase modulation (SPM) is a nonlinear effect which leads to the phase modulation of the SOA output signal. This is caused by the variation in refractive index of optical amplifier since we induce input signal power.

B. Cross-Phase Modulation

The cross-phase modulation (XPM) is also a nonlinear effect, which has same effect as SPM.In this two optical signals are used at the same time .One of the optical signal also called as control signal is responsible for variation in refractive index of the device,and the second optical signal also called as probe signal has phase variation in its output.

C. Four Wave Mixing

In four wave mixing (FWM) as the name suggests it generates new frequencies.In four wave mixing two or more wave propagates through semiconductor optical amplifier in which they interact with each other and this leads to generation of new waves with different frequencies.In comparison to other non linarites of SOA four wave mixing as shown a very promising effect in implementation of logic gates.

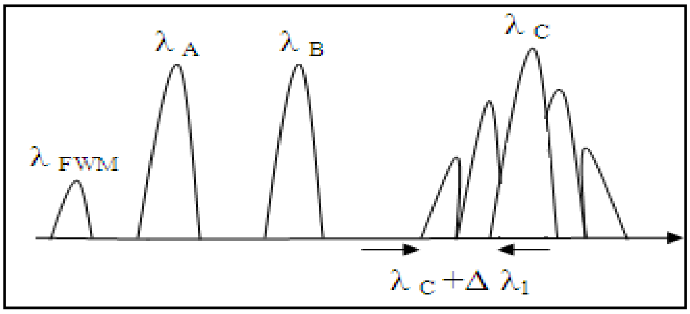

Fig 1:Conjugated light generated and broadened spectrum of the probe due to XGM, XPM and FWM respectively.

When two input signals are passed through semiconductor optical amplifier,the signal which is generated as output has to be adjusted accordingly to generated different logics.

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data A	data B	AND	NOT A
0	0	0	1
0	1	0	1
1	0	0	0
1	1	1	0

Fig 2:Truth Table of logic gates.

III. Simulation Setup

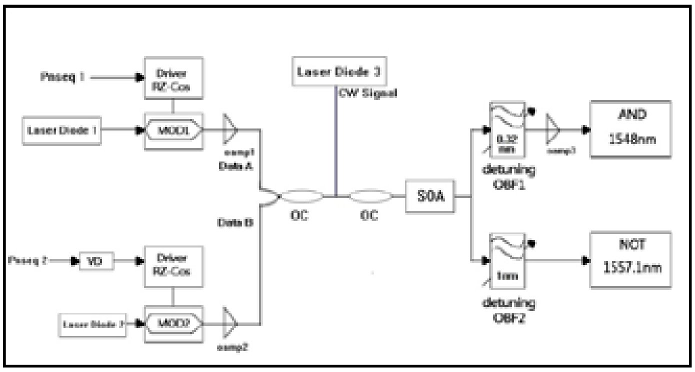

Fig. 3: Simulation Setup

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The configuration is depicted in the figure 2 .In this two continuous wave beams of different wavelengths is generated with the help of laser diode 1 and laser diode 2. Pnseq1 and pnseq2 generate pseudo random bit sequence. The data signals A and B are modulated at 40 Gb/s with the help of two modulators. Optical amplifiers oamp1 and oamp2 are used to amplify data signals. The probe signal (CW) is generated with the help of laser diode 3. SOA is biased at 300mA with line width enhancement factor of 6. The output of logic OR and AND gate is filtered with the help of tenable Gaussian narrow optical band pass filter.

IV. Methodology

All optical logic functions are implemented based on the non linarites of semiconductor optical amplifier .With the proper adjustment of the parameters of semiconductor optical amplifier results into output signal whose power level is adjusted accordingly to generate different logic functions.

Logic Not

XGM in SOA is used to obtain logic not gate output. When either the data signal *A* or datasignal *B* is present, the probe signal is gain-modulated. Hence a polarity-inverted outputsignal is obtained which results in logic NOT output.Due to limitation of cross gain modulation in semiconductor optical amplifier, saturation appears in the output of loginot.Moreover due to this limitation the extinction ratio of logic NOR gate is also very less.

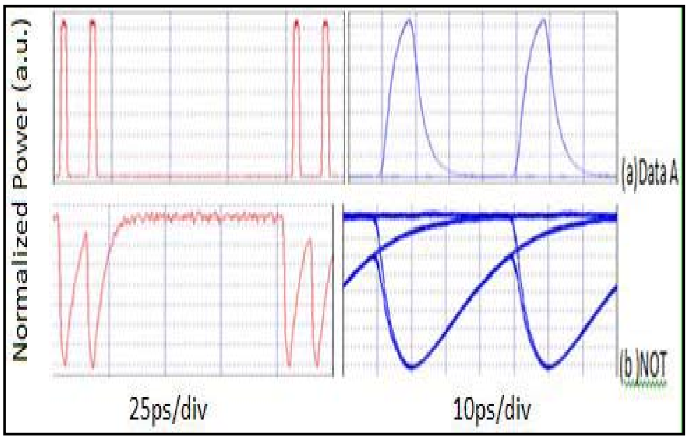

Fig 4: Output of logic NOT gate (a)Data A; (b)Logic NOT;

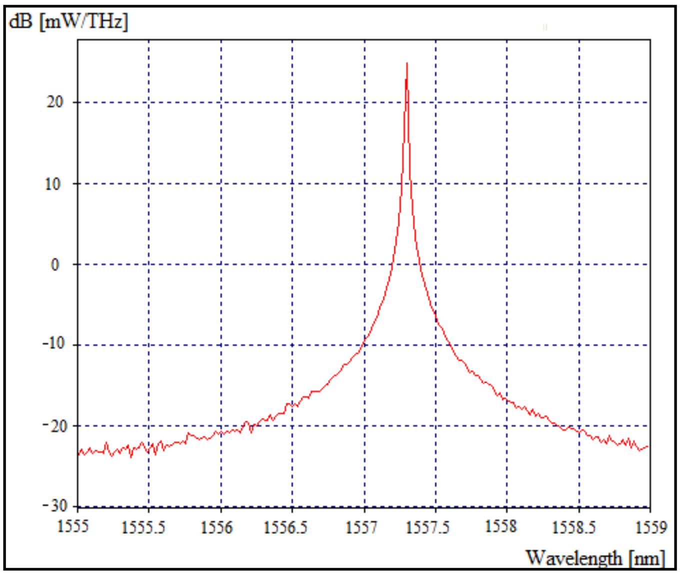

Fig 5: Spectrum of probe signal before SOA

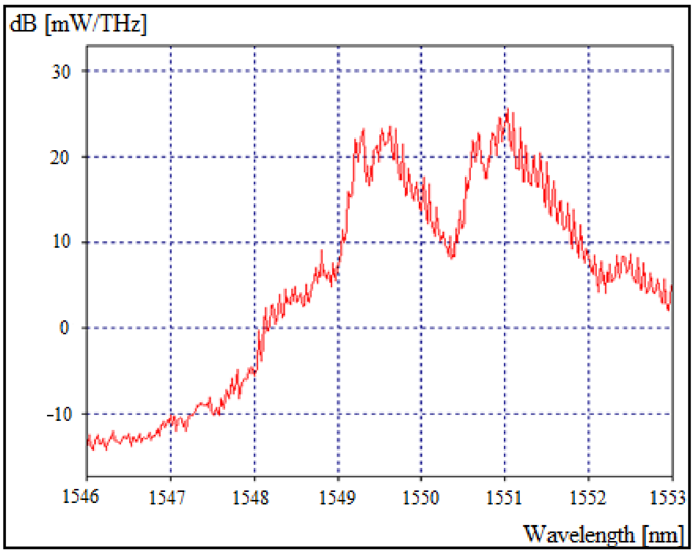

Fig 6 : Spectrum of probe signal at SOA output

Logic And

Logic AND plays a very vital role in optical signal processing. FWM in SOA is used to obtain logic and gate output. In this logic '1' is obtained when the both the data signal*A* and the data signal *B* is present at the same time. When either of the data signal is absent output logic '0' is obtained.Due to limitation of four wave mixing effect the power level of output logic and gate is very less in comparison with not gate. The extinction ratio and contrast ratio of logic and gate is observed to be maximum.

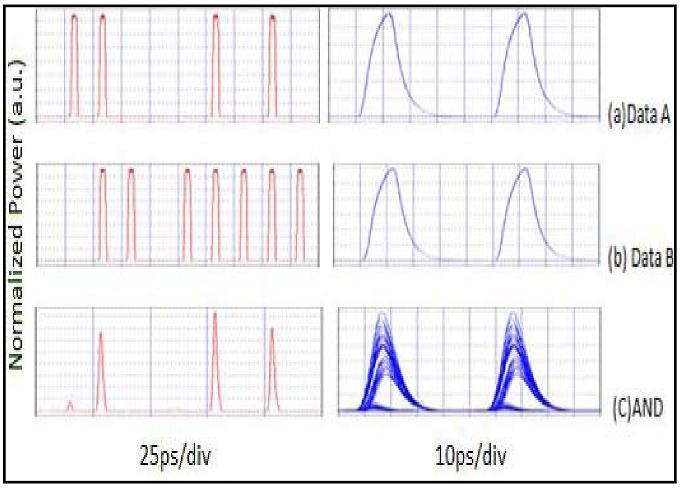

Fig 7:Output of logic AND gate (a)Data A; (b) Data B; (c)Logic AND;

V. Results and Discussion

The performance of different logic gates is analysed with the help of its extinction ratio and contrast ratio.For good performance of logic gate its C.R and E.R must be very high.Higher contrast ratio shows the impact of input signal on output signal.Higher extinction ratio gives good distinguishes between logic level '0' and logic level '1'.Figure shows the graph of extinction ratio and contrast ratio with respect to variation in power level of input signals -3dbm to 3dbm. The extinction ratio obtained for OR, AND and NOT gates are 18.2dB,19dB and 9.7dB.

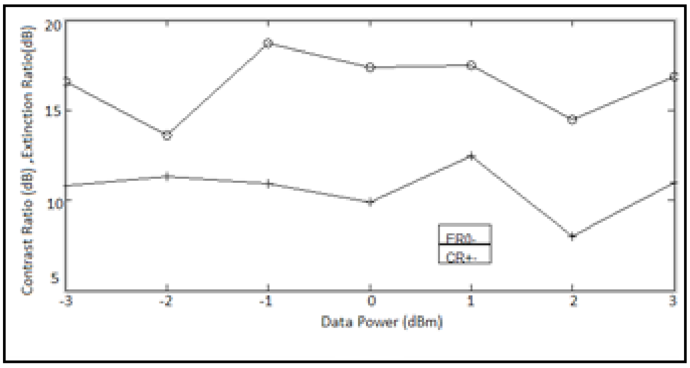

Fig 8: Contrast Ratio and Extinction Ratio of logic AND gate.

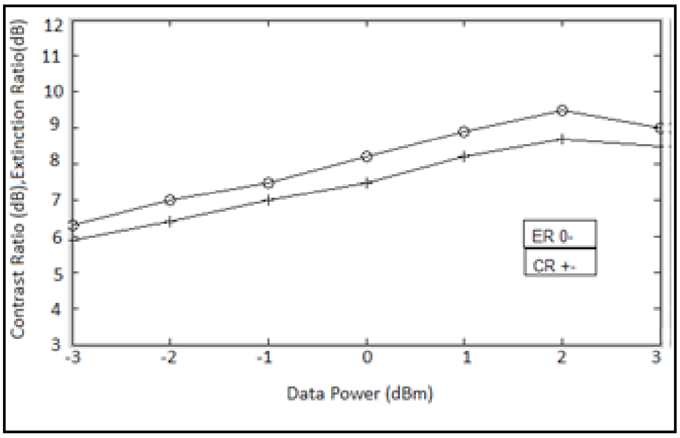

Fig 9:Contrast Ratio and Extinction Ratio of logic NOT gate.

VI. Conclusion

In this paper an architecture is proposed for implementation of optical logic functions AND, OR using the same design.All implemented logic operations are simple and reconfigurable. Contrast ratio and extinction ration has also been analyzed for the implemented logic gates.The maximum value of extinction ratio is found to be 19db and maximum value of contrast ration is 17.2 dB which is quite accurate for logic gates applications

VII. AcknowledgEment

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