Cost Effective Approach to implement all Optical Logic Gates using Semiconductor Optical Amplifier

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Abstract. Optical computing is the future of high speed computational and networking devices, having a prodigious importance in enlarging extremely high speed optical networks. This paper focuses on investigation of various design schemes of SOA (Semiconductor Optical Amplifiers) based MZI AND, OR, XOR, NOT gates exploit the component performance on even very low powers and average high bit rate of 20Gbps, making a comparison of obtained results with latest reports. Conclusions are drawn on the basis of design that substituting couplers instead of modulators provide better results in terms of Q-factor, logical outputs, computational speed at the minor power levels.

Keywords: Optical networks, SOA, modulation, Cross gain, phase modulation, Wave mixing, Gates

1 Introduction

In order to achieve the edge of speed of electronic devices, high bandwidth is desired. Opto-electronic conversion is one of the complex processes in the digital gates [1]. For jam-full benefit of impending of optical fiber in the development of contemporary networks, all-optical gates are obligatory modules without any disadvantage of conversions full of losses which occur in electric domain. SOA used for the designing of gates related to optics. This is due to because SOA provides very high change in the refractive index which is required for the desired logic outputs along with high gain. With the usage of SOA, all-optical gates can be operated at wider bandwidth and undemanding photonic amalgamation is possible [2].

For designing of optical gates, a non-linear medium is required as it enables the modulation of the signal to get the desired output. The nonlinear loop mirror and fibers, acoustic wave filters, waveguide, thyristors, or semiconductor optical fiber generates the nonlinearity. The gain recovery time of SOA induces limitations to this approach having prodigious speed but it can be improved by using band pass filters after SOAs. Detuning of these filters reduces the distortions occurring due to pattern effects. [3]. In literature, number of methods have been used to realize different logic and mathematical operations using nonlinear processes such as cross gain and phase modulation and four wave mixing in SOA using Mach-Zehnder interferometer configuration [4].

The SOAs have various applications apart from generating logic operations like amplification using stimulated emission and wavelength conversions. Using SOA in Interferometry configuration has shown better results till now but sometimes the delay produced in one of the arms is of longer duration that the correct logic is not received at the instance of time. Reportedly configuration used modulators but here i.e. in the current setup couplers are used instead of them.

2 System Setup

Non linearity effect with or without SOA is used in every optical door. Various methods without SOA uses parameters like length, waveguide with attenuator and circulators structures, channels with acoustic optic waves, and changes in refractive index etc.

The information streams A with 1550nm frequency and B with frequencies of 1550.5nm separately are applied through consistent wave (CW) laser sources having 0.8 mW of intensity. The test signal at a 1540 nm frequency is created from another CW laser source. Non straight activities happen in voyaging wave SOA which is one-sided at 600 mA with a line width improvement factor of 5.

The consolidated information stream alongside test signal makes the non-direct medium in SOA. Depending upon the structure of framework arrangement non straight procedure happen inside SOA, which is additionally, trailed by an optical channel whose data transmission and frequency is balanced by the necessary door activity. Various SOA boundaries that are balanced for impeccable SOA execution are appeared in Table-1:

The various ways of generating logic outputs have been reported out of which recently reported is realization of logic gates using components like modulators, SOA etc. The configurations of these gates were simpler than earlier reported gates and quality factor outputs at different parameters have been given.

Parameter	Value
Bias Current	0.6 amp
Length	0.0005m
Width	3x10-06 m
Height	8x10-08 m
Optical Confinement value	0.35
Line width factor	5
Transparency Carrier Density	1.4x1024 m3
Initial Carrier Density	3x1024 m-3
Gain	2.75x10-20 m2

Table 1. SOA Parameters

2.1 XOR Gate

Data signals having comparative or various frequencies are sent through the port 1 and 2 of independent MZI. A ceaseless wave for example the test signal is coupled to port number 3 as the control signal which further parts into halves, one arriving at the upper part and other at the lower branch of interferometer [5]. The presentation of the information signal prompts the regulation of increase and refractive list, causing the stage move over the control signals spreading through the SOAs. These stage shifts happens regarding the force variety of the information signals A and B. The square graph, waveforms and particular eye outline are appeared in Figure. 1, 2 and 3.

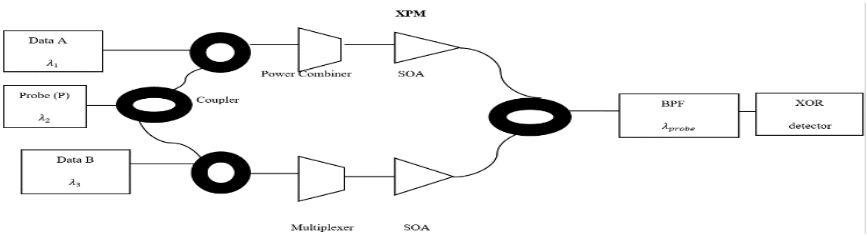

Fig.1. SOA-MZI coupler based XOR logic detection.

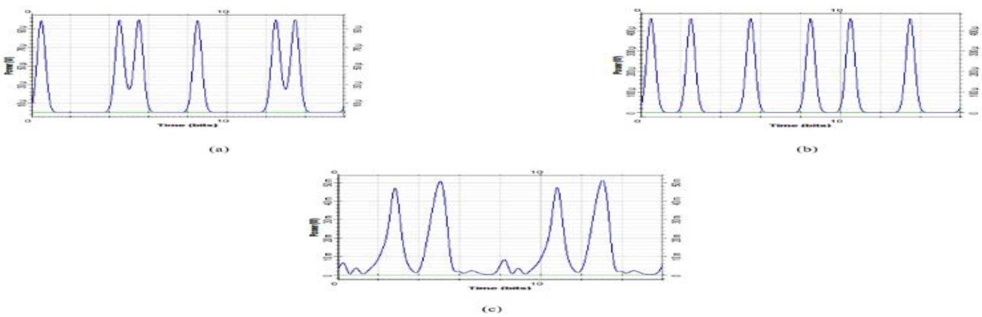

Fig.2. Input signals (a) data A (b) data B and (c) XOR output

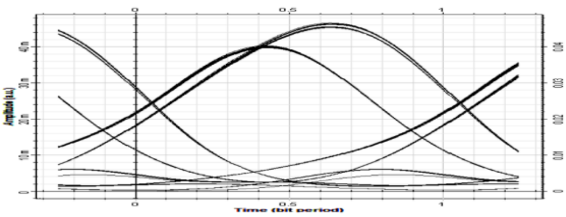

Fig.3. Eye diagram (Q-factor of 36.3) of XOR output

2.2 AND Gate

For the AND entryway, the information signal, data B enters the gadget at port 1 and 3 with port 2 having test signal is grounded. No extra control signal required as for this situation both signals go about as test signal for one another. With the nearness of both the information streams, the FWM happens inside the SOA and novel frequencies are delivered [6]. It must be noticed that FWM relies upon different boundaries, for example, frequency detachment between input signals, input power levels and SOAs boundaries. Utilizing the band pass channel after SOA at suitable frequency and data transfer capacity, the AND activity is accomplished. The square graph, waveforms and separate eye chart are appeared in Figure. 4, 5 and 6.

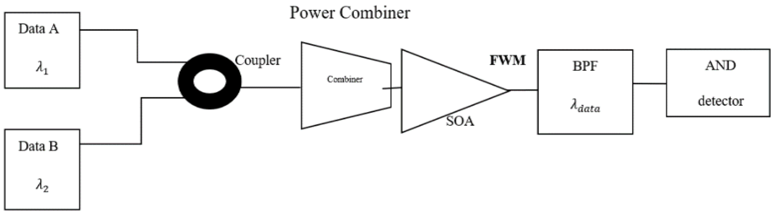

Fig.4. SOA-FWM coupler based AND logic detection

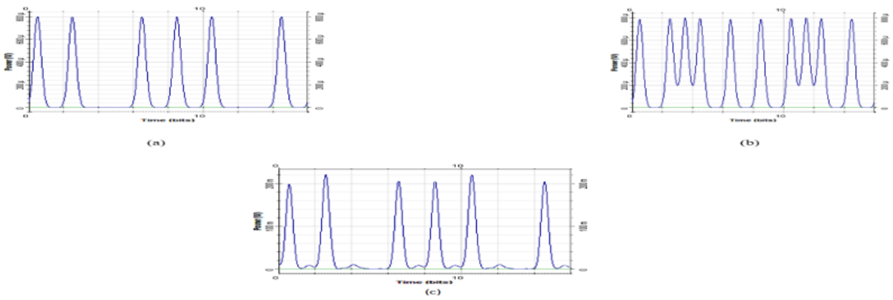

Fig.5. Optical waveform of input waveforms (a) data A (b) data B (c) XOR output

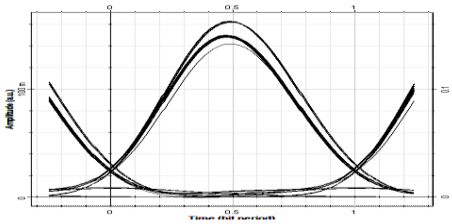

Fig.6. Eye diagram of AND output with Q-factor of 105.12

2.3 OR Gate

For OR gate, no MZI design is required, both the information signals are joined at a similar port [7]. As a result of the XGM and XPM nonlinear procedures, the falling edge of the sign is additionally moved towards a more drawn out frequency and the rising edge is moved towards a shorter frequency, therefore range is enlarged. With this, we accomplish the OR door activity. The square graph, waveforms and particular eye chart are appeared in Figure 7, 8 and 9.

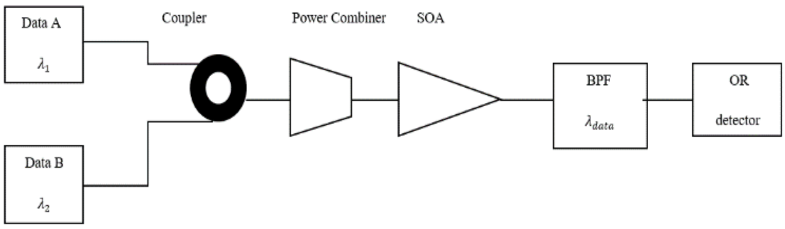

Fig.7. SOA-MZI coupler based OR logic detection

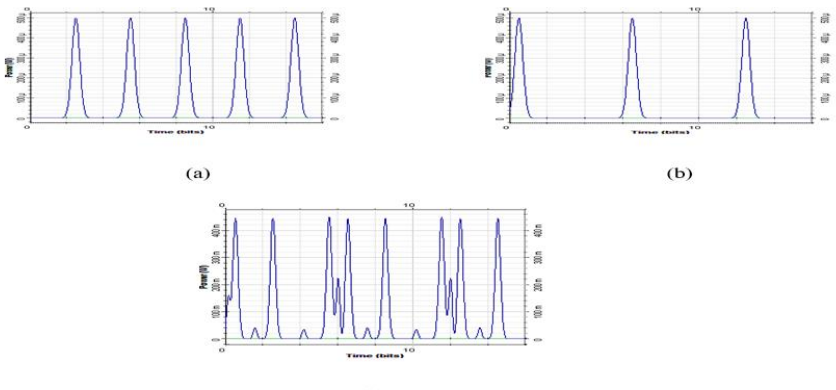

Fig.8. Optical waveform of input signals (a) data A (b) data B (c) OR output

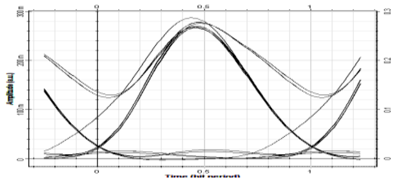

Fig.9. Eye diagram (Q-factor of 30.56) of OR output

2.4 NOT Gate

For the NOT Gate, one of the two (A or B) is shot with test signal to SOA [8,9]. The adjusting boundary when consolidates with the test signal, brings about the altered extremity of test and NOT rationale is accomplished. 10GHz transfer speed is adequate for the NOT activity. The square graph, waveforms and separate eye chart are appeared in Figure 10, 11 and 12.

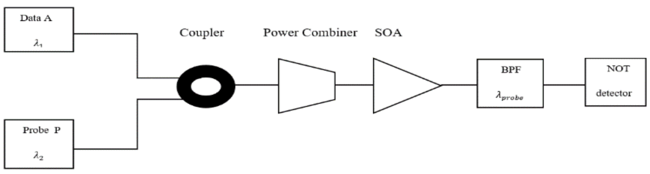

Fig.10. SOA-MZI coupler based NOT logic detection

(a) (b)

Fig.11. Optical waveform of input signals: (a) data A (b) NOT output

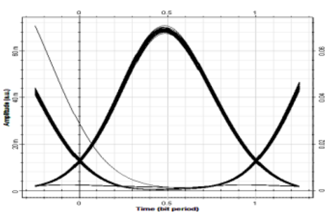

Fig.12. Eye diagram with Q-factor of 56.80 of NOT gate output

3 Results with Discussions

SOA shows highly nonlinear qualities for various logic input. Utilizing XGM in SOA Optical OR and NOT gates are acknowledged while the XOR doors are executed utilizing FWM and SOA-MZI nonlinear procedures. The plot of intensity versus nature of NOT gate shows the impromptu creation in Q-factor as appeared in Figure 13.

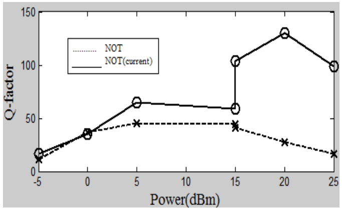

Fig.13. Power Vs Q-factor for NOT gate

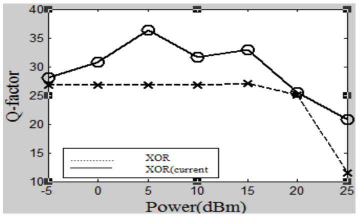

Fig.14. Plot for improved quality factor for XOR gate

The new pulse generated is phase conjugate imitation of the probe pulses, and can be extracted using an optical filter of 20GHz bandwidth.
FWM nonlinear procedure empowers the system to acknowledge AND logic. An ideal AND gate required speed of 60GHz for their operation due to the minor competence of FWM.

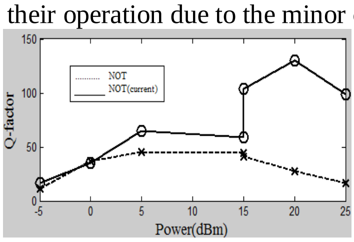

Fig.15. Plot of improved quality factor of AND gate for different values of power

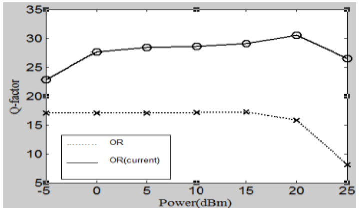

Fig.16. Plot of improved quality factor of OR gate for different values of power

The combination of data stream when introduced in the SOA modulates the carrier, further leading to the modification in gain and phase of the probe signal causing XGM and XPM. The plotting clearly indicates the marginal difference of Q-factors by using couplers instead of modulators as shown in Figure 16.

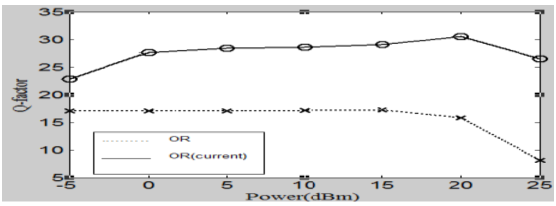

Fig.16. Plot of improved quality factor of OR gate for different values of power

Table 2. Quality factor for different input power

Quality factor				
Input power (dBm)	**OR**	**AND**	**NOT**	**XOR**
-5	22.83	8.89	16.23	28.02
0	27.69	18.94	35.17	30.80
5	28.39	18.84	65.08	36.35
10	28.57	105.12	59.26	31.67
15	29.12	20.53	103.52	32.92
20	30.56	28.72	130.04	25.43
25	26.53	28.17	98.61	20.77

From the table shown above it is evident that high quality factors are achievable with low power consumption using couplers instead of modulators. Making use of coupler which is less expensive comparative to modulator decreases the manufacturing cost of the setup, thus, making it a less expensive, power efficient and good quality setup.

4 Conclusion

In this work optical gates have been designed using SOA. Performance is evaluated on the basis of quality factors and observed that using couplers in the same configuration instead of modulators can give higher operational speeds along with the high quality factor and received power. System has become more power efficient and inexpensive as use of expensive and bulkier components like HNLF and modulators have been eliminated. In future, this system can be used to high quality and power efficient sequential circuits like comparators, encoders etc.

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Biography

Dr.Simarpreet Kaur received the bachelor's degree in Electronics and Communication Engineering from Chandigarh Engineering College, Landran, Punjab Technical University, Jalandhar in 2013, the master's degree in Electronics and Communication engineering from Punjabi University, Patiala in 2015, and the philosophy of doctorate degree in Electronics & Communication Engineering from Punjabi University, Patiala in 2020, respectively. She is currently working as an Assistant Professor at the Department of Electronics and Communication Engineering, Chandigarh Engineering College, Landran,. Her research areas include fiber optic networks, Information security, wireless communication. She has been serving as a reviewer for many highly-respected journals.