# Secured High Speed Transmission in Optical Communication Systems

**Afreenzehra Sayed, Lochan Jolly**

*Abstract*—**At first, fiber optic networks were touted as one of the most secure infrastructure options. In the last few years, it has been suggested that fiber is almost as easy to tap as copper. Hence one of the solutions is to encrypt the data before transmission. This paper proposes the comparison of two techniques in building a secure communication network by employing XOR gate using cross gain modulation and cross phase modulation at high data rates of 120Gbps. The performance of both the systems were monitored which is in good agreement with theory.**

***Index Terms***— **Cross gain modulation (XGM), Cross phase modulation (XPM), Mach-Zehnder Interferometer (MZI), Semiconductor optical amplifier (SOA).**

## I. Introduction

Due to increased demand of high bandwidth and speed for all optical processing of signals like clock recovery, address recognition, packet synchronization and signal regeneration there is a need to design optical logic gates with all optical components [1]-[3].Thus these basic necessities lead researchers to design various logic gates in optical system with and without semiconductor optical amplifier (SOA) [3], [4]. SOA being the popular element for its nonlinear operation it offers a promising candidature for implementation of gates [1], [3], [4].This paper deals with implementation of security in optical communication systems by constructing XOR utilizing optical components to avoid cumbersome opto-electronic conversion [5].XOR gate is the basic building block for any encryption algorithm e.g. DES. By means of symmetric SOA-MZI structure and single SOA, XOR gate is implemented using cross phase modulation (XPM) and cross gain modulation (XGM) respectively [1]. The nonlinear behavior of semiconductor optical amplifier leads to the formation of XOR logic gate suitable for secure optical communication at high data rates. In the past many methods were used to construct different gates such a terahertz optical asymmetric demultiplexers (TOAD), ultrafast nonlinear interferometers (UNIs), Michelson Interferometer, Delay interferometer and Mach-Zehnder interferometers [5], [6] as shown in the Fig. 1. The use of Mach-Zehnder interferometer is more favorable due to its simplicity, requirement of low power, compactness, stability and integrability. In this paper an effort is made to compare two techniques to implement security at high data rates using XPM and XGM at 120Gbps.

*Manuscript received Nov, 2014*.
***Afreenzehra Sayed****, Electronics and Telecommunication, Mumbai University., Mumbai, India, 8108384005*
***Lochan Jolly****, Electronics and Telecommunication, Mumbai, India, 9821991509.*

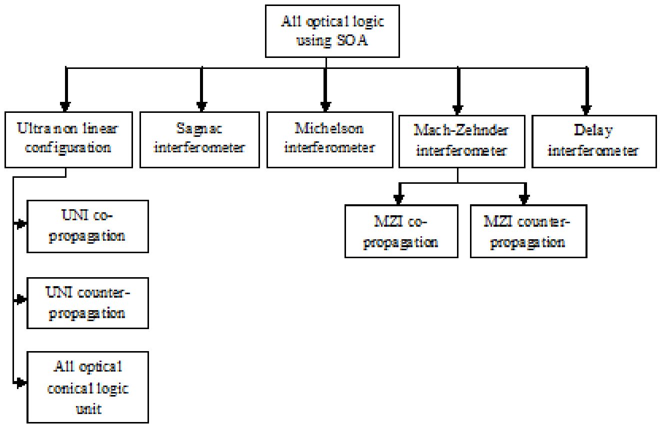


**Fig. 1: Techniques for All optical Logic gates [5].**

## II. Block Diagram Representation of XOR Gate Using XGM at 120Gbps

The two data streams Data and key signal having wavelength of 1550nm were generated at 120Gbps using CW lasers. As opposed to the simulation set up of XPM here the data and key signal is generated separately using the custom files of respective PRBS generators [7].

An optical multiplexer is used to combine the data and key signal to form a single stream. This combined data stream is then amplified using an Erbium doped fiber amplifier (EDFA) to boost the level of input signals. The probe signal of wavelength 1559nm is generated using CW laser at 120Gbps [1], [7]. This probe signal is having a random sequence at 120Gbps.

The combined data stream along with the probe signal is introduced into the Travelling wave Semiconductor optical amplifier (SOA) through an optical multiplexer. Inside the



ISSN: 2278 – 7798 

semiconductor optical amplifier the variation of input power causes gain variation in SOA [7], [8]. With the increase in input power, SOA gets depleted of its carrier which leads to the reduction in gain and vice versa. This conversion takes place in the order of picoseconds and so it is possible to use this variation on the gain with bit to bit fluctuations of the input power [5]. The optical filter tuned at 1650nm and bandwidth of 0.1nm gives XOR output. The values of SOA parameters used to realize this XOR gate is given in the Table 1. Fig. 2 shows the block diagram for XOR gate using cross gain modulation [7].

**Table I : SOA Parameter Values (XGM)**

| **Parameters** | **Values** |
|---|---|
| Pump Current | 0.3 mA |
| Confinement factor | 0.15 |
| Recombination Constant A | $1.43\times10^{8}$/s |
| Recombination Constant B | $1\times10^{-16}m^{3}/s$ |
| Recombination Constant C | $3\times10^{-41}m^{6}/s$ |
| Length | 500µm |
| Width | 3µm |
| Thickness | 0.08µm |
| Internal Loss | 900/m |

## III. Block Diagram Representation of XOR Gate Using XPM at 120Gbps

Pseudo random sequence is given as data input in the RZ format at 120Gbps and this then modulated by Lorentzian laser at 1558.2nm wavelength for 1mW of input power. The key signal for encryption is generated by providing a delay of 80ps to the same sequence which is then modulated at the same wavelength and input power of 1mW. This two modulated signals are applied to the 3dB coupler which is then splitted using two splitters. One output of each splitter is directly connected to each of the SOA and the other is connected via EDFA amplifier [9], [10].

The two SOA's are connected in such a manner to make symmetric co-propagating Mach-Zehnder interferometer because it is reported to have better performance [11]. The parameter values of SOA's are so adjusted that they perform cross phase modulation. The change in the intensity of the signal causes change in the refractive index of the material which leads to phase change. The SOA-MZI structure converts phase modulation into intensity modulation. The output of the two SOA's are combined using a coupler. The signal is then filtered by Lorentzian filter having centre frequency of 1558.2nm to get the encrypted signal [9], [10]. The values of SOA parameters are used to realize this XOR gate using cross gain modulation as shown in Table II. Fig.3 shows the block diagram for XOR gate.

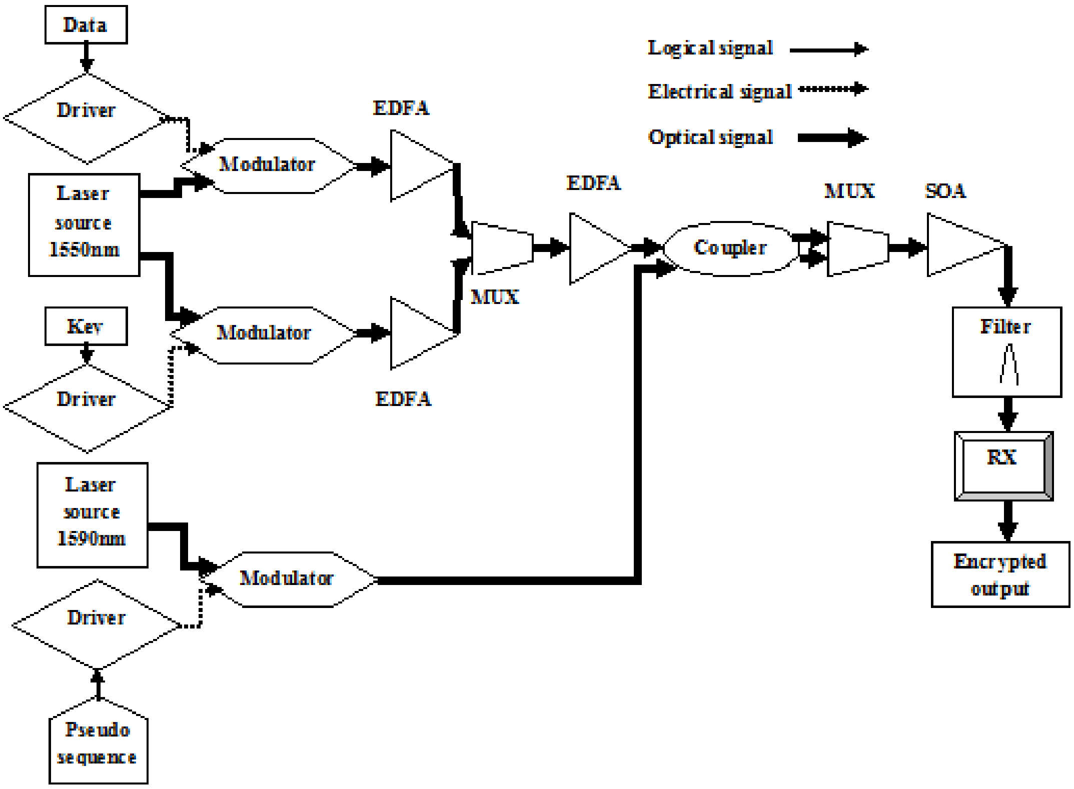


**Fig. 2: Block diagram for XOR gate using XGM [6].**


ISSN: 2278 – 7798 

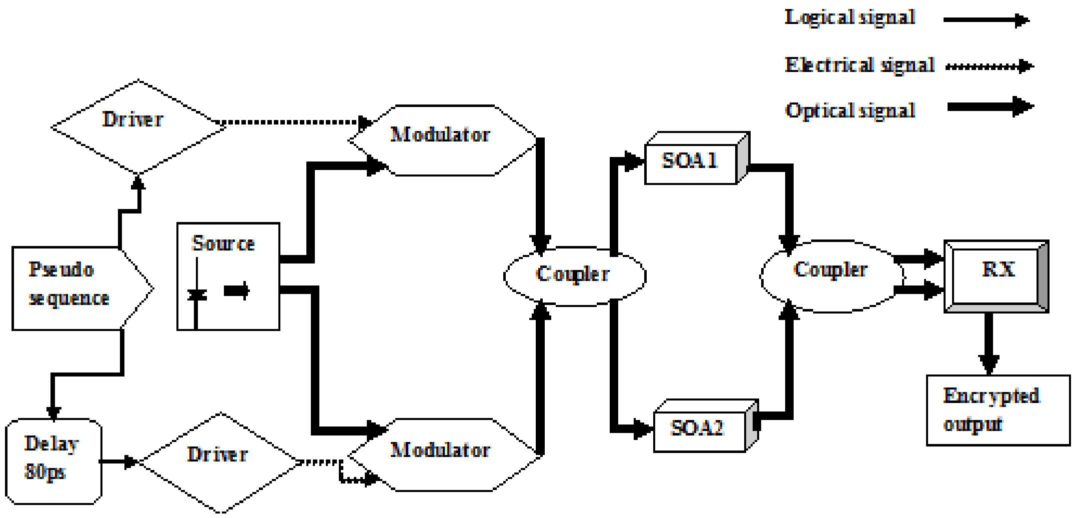


**Fig. 3: Block diagram for XOR gate using XPM [9], [10].**

**Table II: SOA Parameter Values (XPM) [9], [10].**

| **Parameters** | **SOA1** | **SOA2** |
|---|---|---|
| Bias Current | 180 mA | 180 mA |
| Confinement factor | 0.3 | 0.3 |
| Length | 700µm | 700µm |
| Width | 1µm | 1µm |
| Thickness | 0.2µm | 0.2 µm |
| Spontaneous Carrier lifetime | 0.15ns | 0.15ns |
| Transparency carrier density | $1\times10^{24}/m^3$ | $1\times10^{24}/m^3$ |
| Material gain constant | $2\times10^{-20}m^2$ | $2\times10^{-20}m^2$ |
| Line width enhancement factor | 300/m | 300/m |
| Material loss | 1050/m | 1050/m |
| Saturation power | 28.48mW | 28.48mW |
| I/p and o/p insertion loss | 3dB | 3dB |

## IV. Results and Discussion

The two techniques presented in this paper to build XOR gate shows the simulation result performed on Optsim 5.1 software. The simulated block diagram is divided into three sections transmitter, SOA section and receiver section which is shown in Fig. 4 (a), Fig. 4 (b) and Fig. 4 (c) respectively. Encrypted signal using XGM at 120Gbps

### *A. Encrypted signal using XGM at 120Gbps*

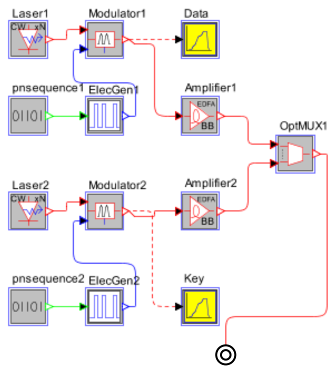


**Fig. 4 (a): Transmitter section of simulated block diagram (XGM)**

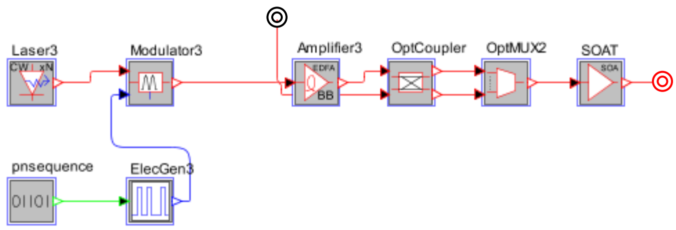


**Fig. 4 (b): SOA section of simulated block diagram (XGM)**

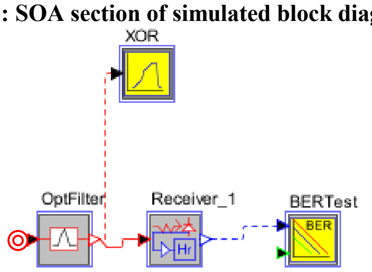


**Fig. 4 (c): Receiver section of block diagram (XGM)**



ISSN: 2278 – 7798

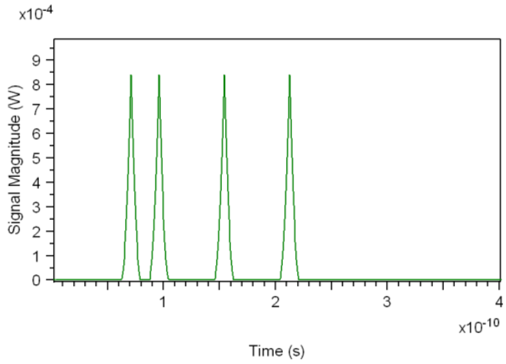


**Fig. 5 (a): Input data signal**

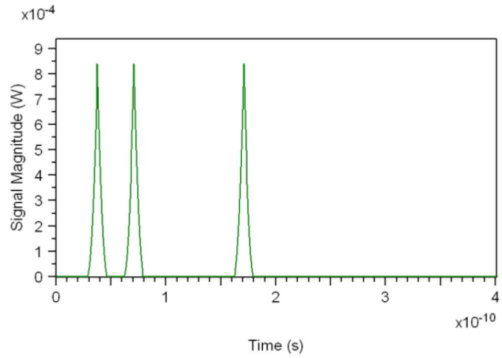


**Fig 5 (b): Input key signal**

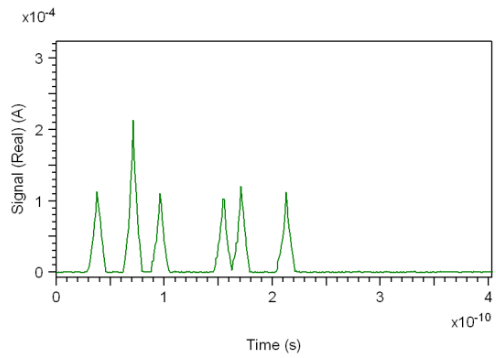


**Fig. 5 (c): Encrypted output waveform**

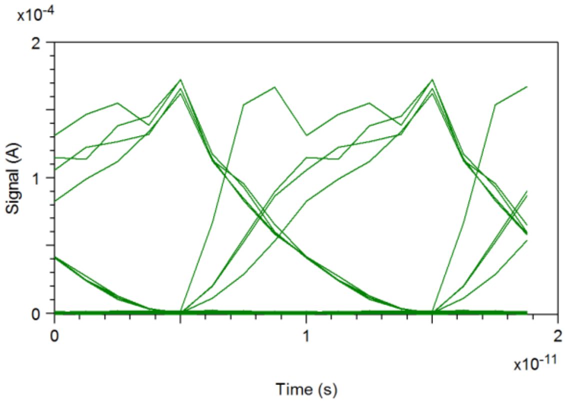


**Fig. 5 (d): Eye diagram at120Gbps**

Fig. 5 (a), Fig. 5 (b), Fig. 5 (c) and Fig. 5 (d) shows the data signal, key signal, encrypted output and eye diagram respectively. Both the signals are at 120Gbps and an input power of 1mW. It is observed from all the three figures that there is reduction of power level at the output. Recently, it has been discovered that the RZ-modulated signal undergoes less intersymbol interference in the receiver and is more robust to BER nonlinearities and thus more capable of long-haul data transmission [12]. Hence it was observed that the performance of output showed better results with RZ encoding than NRZ encoding. The Bit Error Rate (BER) of $1.9143\times10^{-3}$ and Quality Factor (Q) of 9.223dB were observed.

*B. Encrypted signal using XPM at 120Gbps*

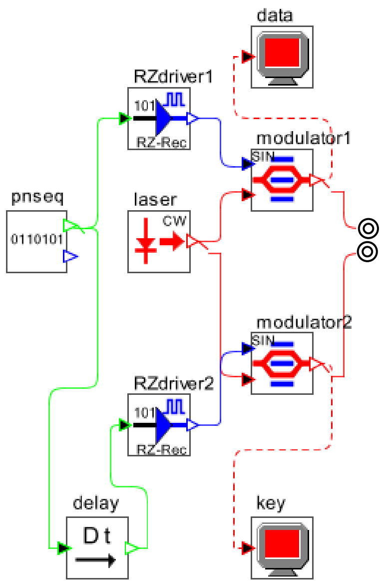


**Fig. 6 (a): Transmitter section of simulated block diagram (XPM)**

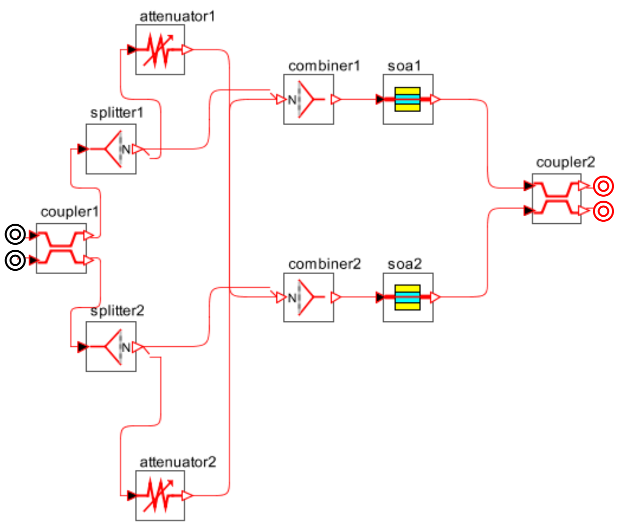


**Fig. 6 (b): SOA section of simulated block diagram (XPM)**



ISSN: 2278 – 7798 

Fig. 6(a), Fig. 6 (b) and Fig. 6 (c) shows three sections of the simulated system which is transmitter, SOA and receiver section. Fig. 7 shows the encrypted output. It is observed that the output signal has increased power level, greater than 12 mW when both the input signals had input power of 1 mW. The Fig. 8 shows eye diagram which gives us BER of $4.844 \times 10^{-9}$ and Q factor of 15.142dB. The results are in good agreement with theory.

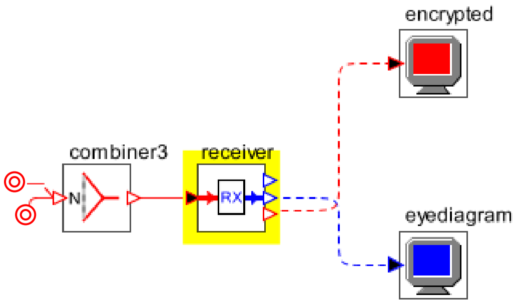


**Fig. 6 (c): Receiver section of block diagram (XPM)**

In XGM gain compression caused by the modulation of carrier density is accompanied by phase modulation due to the associated change in the refractive index. This results in the chirping of the optical data stream which leads to degradation of performance. In XPM this drawback becomes an advantage by placing the SOA in an interferometric configuration which converts phase modulation to intensity modulation [13]-[15]. Table III shows comparative result of encrypted signal at 120Gbps by two methods.

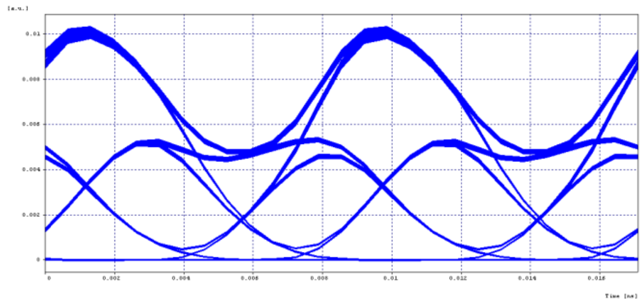

**Fig. 8: Eye diagram at 120Gbps**

**Table III. Comparative results of XGM and XPM**

| Measuring Parameters | XGM | XPM | Percentage improvement |
|---|---|---|---|
| BER | $1.9143 \times 10^{-3}$ | $4.844 \times 10^{-9}$ | 99.99 |
| Q factor | 9.223 | 15.142 | 64.1765 |

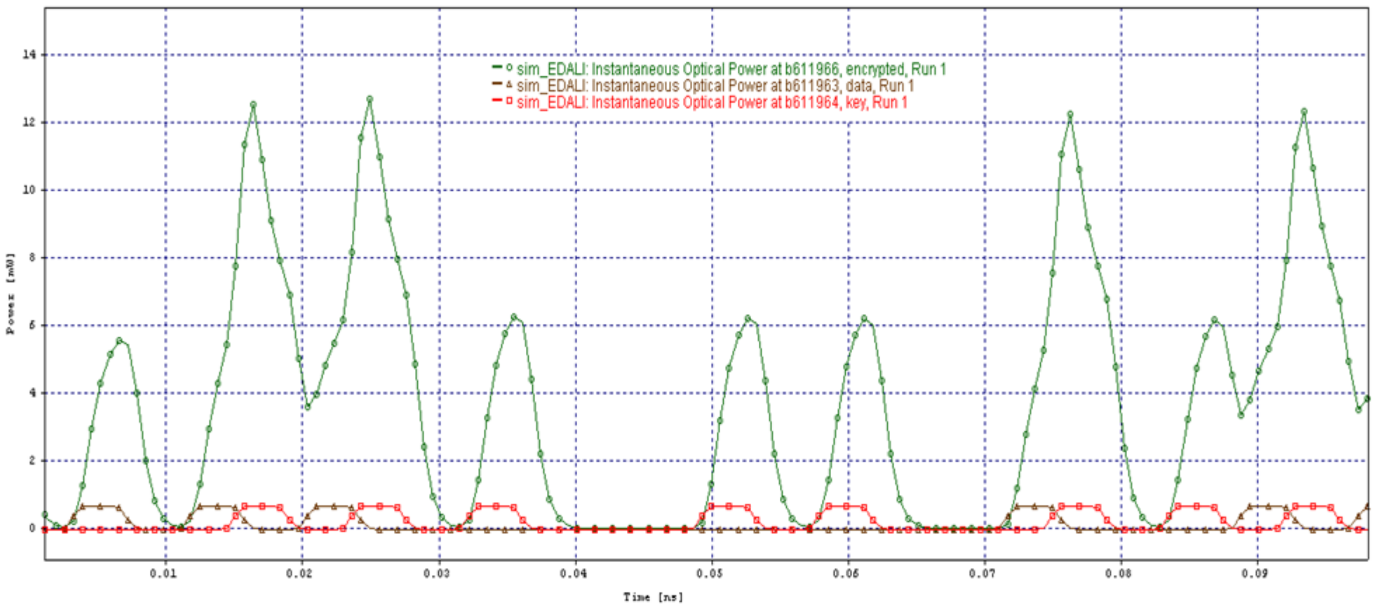


**Fig. 7: Encrypted output waveform**



ISSN: 2278 – 7798 

## V. Conclusion

In two ways the analysis of performance of the encrypted system was made at 120Gbps. The analytical study of two systems shows that the chirp becomes less when SOA's are placed in an MZI configuration in XPM in contrast to XGM and hence will find its application in achieving confidentiality and privacy. Hence it was observed that construction of secured system using XPM has improved performance as compared to the one with XGM by 64 percent.

## REFERENCES


[1] M. Jose, "Photonic Logic Gates: Boosting All-Optical Header Processing in Future Packet-Switched Networks," *Valencia Nanophotonics Technology Center*, Dec 2006.

[2] C. Bintjas, K. Vlachos, N. Pleros and H. Avramopoulos, "Ultrafast Nonlinear Interferometer (UNI) Based Digital Optical Circuits and Their Use in Packet Switching," *IEEE Journal of Lightwave Technology,* vol 21, No. 11, Nov. 2003, pp. 2629-2637.

[3] A. Kumar, S. Kumar, and S. K. Raghuwanshi, "Implementation of All-Optical Logic Gate Using SOA-MZI Structures," *TOEOC*, 2013, pp. 13-21.

[4] S. Kumar, "Semiconductor Optical Amplifiers Performance Optimization in Optical Communication System," *International Journal of Computer Science & Engineering Technology,* vol 3, No. 9, Sept 2012, pp. 390-398.

[5] P. Singh, D. Tripathi, S. Jaiswal and H. Dixit "All Optical Logic Gates: Design, Classification and Comparison," Hindawi Publishing Corporation, *Advances in Optical Technologies*, 2014.

[6] M. Zhang, Y. Zhao, L. Wang, J. Wang and P. Ye, "Design and Analysis of All-Optical XOR Gate Using SOA- Based Mach-Zehnder Interferometer, "*Optics Communication*,2003,pp. 301-308.

[7] B. Kadam and N. Gupta, "All Optical XOR Gate Using Single SOA At 100Gbps," *International Journal of Computational Intelligence Techniques*, vol 2, Issue 2, 2012, pp. 86-89.

[8] V. Thakur, G. Pandove and T. Gupta, "Optical Wavelength Converters Based on Cross Gain Modulation and Cross Phase Modulation in SOA," *International Journal of Electronics and Computer Science Engineering,* vol. 1, No.3, pp. 1274-1280.

[9] S. Singh , Lovkesh, X. Ye and R. Kaler, "Design of Ultrafast Encryption and Decryption Circuits for Secured Optical Network, "*IEEE Journal of Quantum Electronics*, vol 48, Issue 12, Dec 2012,pp. 1547-1553.

[10] S. Singh and Lovkesh, "Ultraspeed Optical Signal Processing Logic Based on an SOA-MZI" *IEEE Journal Of Selected Topics in Quantum Electronics*, vol 18, Issue 2, 2012,pp. 970-977.

[11] H. Minh, Z. Ghassemlooy and W. Ng, "Crosstalk Suppression In All-Optical Symmetric Mach-Zehnder (SMZ) Switch By Using Control Pulses With Unequal Powers," Optical Communications Research group, Northumbria University,2014.

[12] O. Sinkin, "Calculation of Bit Error Rates in Optical Fiber Communication Systems in the Presence of Nonlinear Distortion and Noise," Ph.D. dissertation, Maryland University, 2006.

[13] I. Kaminow and T. Li, "Optical Fiber Telecommunications IV-A: Components," Academic Press, May 2002, pp 718-719.

[14] Y. Guan and R. Wang, "Demonstration of an Optical Switch Based on SOA-MZI Operation at 10Gbps," *International Conference on Artificial Intelligence and Software Engineering*, Atlantis Press, 2013, pp. 239-241.

[15] K. E. Stubkjaer, "Semiconductor Optical Amplifier-based All-Optical Gates for High-Speed Optical Processing", *IEEE J. select Top. Quantum Electron*, vol. 6, No. 6, pp. 1428-1435, 2000.



**Afreenzehra Sayed** completed her B.E degree in the year 2012 and currently pursuing her M.E degree from Mumbai University. She is working at St. Francis Institute of Technology as a Lecturer since 2013 in the Department of Electronics and Telecommunication. Her present research area focuses on secured optical communication network.



**Lochan Jolly** was awarded PhD degree from SNDT University in 2012. She is working at Thakur College of Engineering as Assistant Professor in the Department of Electronics and Telecommunication. She has 16 years of teaching experience. Her present research area is device modeling of MESFET for optical sensor application.




ISSN: 2278 – 7798 