# Ultrafast Optical Message Encryption-Decryption System Using Semiconductor Optical Amplifier based XOR Logic Gate

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***Abstract*— A new type of encryption system is demonstrated at 120 Gb/s which is based on cross phase modulation effect in semiconductor optical amplifier (SOA). Encryption process is achieved by using SOA based XOR logic gate. The feasibility of proposed encryption system is verified through simulation. It has also been demonstrated that proposed encryption decryption scheme exhibit better performance than existing XOR logic scheme in terms of data rate and quality factor.**

## I. Introduction

Encryption plays a vital role in providing security to data transmission. To retrieve information from cipher text, receiver must have encryption key [1]. Electronically data can be easily encrypted at low data rate but as the optical speed increases beyond 10 Gb/s encryption techniques becomes more complex and expensive [2]. To address this problem, there has been an increased interest in substituting electronic encryption systems with all optical components based encryption techniques. In [3], Lelin Yi et. al. has proposed novel encryption method by using Stimulated Brilloin Scattering (SBS) in optical fiber at 10 Gb/s. Later this scheme was considered as non feasible since scattering may cause loss of information. Ben Wu et. al. [4] proposed a novel concept of interference cancellation in optical encryption. In this technique, message signal could only be recovered from encrypted signal by matching interference noise and cancellation noise.

In this paper, a novel encryption decryption scheme based on optical XOR logic using SOA in cross phase modulation mode is presented. Encryption can be achieved by XOR operation performed between data bits and key. At the receiver end, signal is decrypted before detection. Encrypted signal is given as input to the XOR whereas key sequence is same as key used in encryption. Plaintext signal can be retrieved from XOR operation between encrypted signal and key. The proposed technique has reported significant performance up to ultra high speed of 120 Gb/s .The proposed scheme offers manifold advantages like high Q factor, low power requirement, compatible at ultra high speed, negligible penalty in extinction ratio and no requirement of synchronization at transmitter and receiver. These attractive features make our system practically implementable.

## II. Proposed SOA-MZI based XOR logic

Proposed XOR logic works based on cross phase modulation scheme (XPM) in SOA. XPM scheme relies on the change of refractive index of SOA active region. An incoming intensity modulated signal depletes the carrier density of active region of SOA, which results in modulation of refractive index and thereby results in phase modulation of continuous wave signal which is injected along with intensity dependent pulse [5]. As SOA refractive index can be varied, it can be used as optical phase shifter. The two phase modulated wave travelling in two arms of MZI is made to interfere constructively or destructively at the output of interferometer. For constructive interference 1 is obtained and for destructive interference 0 is obtained. During propagation through upper and lower arm of SOA, continuous wave experiences phase modulation given by following equation [5]:

$$\Delta\varphi = 2\pi\mu(L/\lambda) + \alpha[\mathrm{Log}\, G - \mathrm{Log}\, G_o]$$

Where $\lambda$ is wavelength of input signal, L is length of active region of SOA, μ is the refractive index in the absence of input signal, α is SOA linewidth enhancement factor, G is gain in saturated region and $G_o$ is linear gain of SOA.

Proposed design of XOR logic is shown in figure 1. XOR operation is performed between two optical signals termed as signal A and signal B.

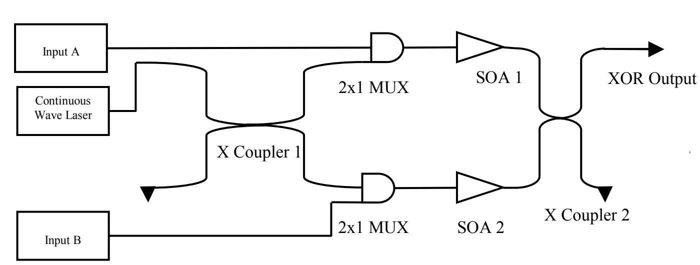


Fig 1. Proposed XOR logic based on SOA-MZI

*A.* Case 1 for A=0 and B=0

For A=0 and B=0, i.e. in the absence of pulse, refractive index of upper and lower SOA remains constant. Each coupler connected at the input and output port of interferometer produces phase shift of $\pi/2$ for the beam that comes from opposite port of coupler. The two beams after passing through SOA would recombine at the output port of X coupler2. At the time of recombination total phase difference between the beams becomes $\pi$ which means two beams combine each other destructively i.e. 0 is obtained.

*B.* Case 2 for A=1 and B=0

Under this case of A=1 and B=0, refractive index of upper SOA changes due to arrival of data pulse whereas lower SOA refractive index remains unchanged. CW beam traveling through upper arm experiences phase shift of $\pi$ due to changed refractive index of $SOA\,1$. Considering phase shift of two couplers and phase shift caused by upper arm SOA, two beams meet at output of coupler 2 with zero phase difference or constructively which means logic 1 is obtained.

*C.* Case 3 When A=0 and B=1

For A=0 and B=1, refractive index of lower SOA changes due to arrival of data pulse whereas upper SOA refractive index remains unchanged. This case is very similar to case 2 and two beams meet at output of coupler 2 constructively i.e. logic 1due to phase difference of $\pi$ between them.

*D.* Case 4 for A=1 and B=1

For the last case where, A=1 and B=1,refractive index of both SOA changes due to arrival of a data pulse, such that CW beam from lower arm and upper arm interferes destructively at the output of coupler 2 i.e.0 is obtained.

## III. Results and Discussion

The eye diagram of the encrypted signal of proposed design is shown in figure 2 which is shows a high Q factor value of more than 55 with output power of 12 dBm. Eye diagram of decrypted signal after travelling through 100 km optical fiber is shown in figure 3. Decrypted signal is shows a quality factor of more than 25 with 9 dBm power.

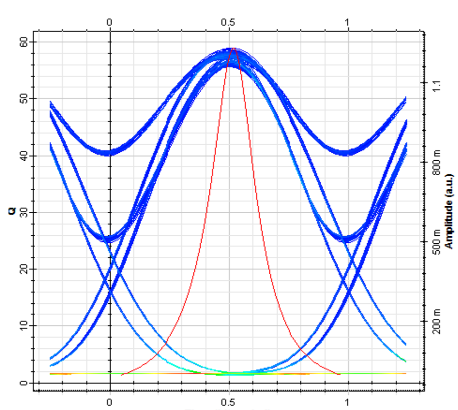


Fig. 2. Encrypted signal Eye diagram at 120 Gb/s

These results are better than result of ref [6] in terms of data rate and quality factor. Improvement in peak power and extinction ratio is observed in proposed encryption method over [6] even at 120 Gb/s. Patterning effect distortion [5] is detected in eye diagram of decrypted signal, which is caused due to slow carrier recovery time of SOA.

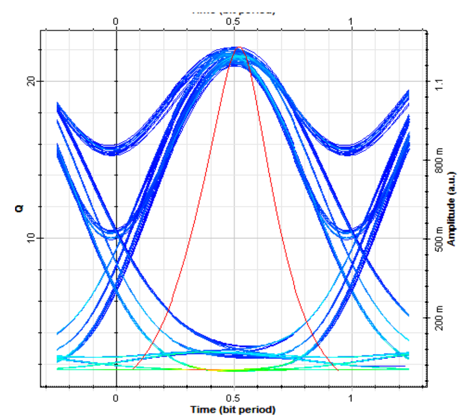


Fig. 3. Decrypted signal Eye diagram at 120 Gb/s

## IV. Conclusion

In this paper a low complexity approach to secure data transmission in optical networks was presented. Our approach implements SOA-MZI based XOR logic to encrypt and decrypt message signal at ultra high speed in optical domain. The simulation results show excellent performance at ultrafast data rate of 120 Gb/s and confirm practical implementation of proposed experiment setup. It is impossible for an eavesdropper to decode message signal from encrypted signal without knowing the Key, XOR logic design and SOA parameters.

## References

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