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Investigations with All Optical NOT Logic Gate

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***Abstract*—Presently world is incessantly stirring towards digital revolution, technology which further enhances the momentum, security and span of information turnover, for that all optical design is must. In this sight this article explores investigated performance for all optical NOT logic operation. The stated logic operation has been verified and performance investigated for span of data rate 5 to 30 GHz for numerous key design parameters. The design makes use of SOA and RSOA, whose non linear behavior is exploited to realize NOT logic gate execution. Numerically simulated outcome have verified the output waveform. Further, results depicted that performance is better with RSOA and non return to zero modulation format. Numerical simulations have illustrated better performance for 0.5W peak laser power, lower average normalizer power, large active length, width and thickness of RSOA. The performance investigation have acknowledged for the significant factors and their function in the design of inverter logic operation and they must be appropriately picked and joined altogether in order to construct certain the efficient operating conditions for an optical link.**

***Keywords*— advanced semiconductor fabrication technology (ASFT), nonlinear element (NLE) semiconductor optical amplifier (SOA), cross phase modulation (XPM), cross-gain modulation (XGM).**

I. INTRODUCTION

The hasty increase of global subscribers, advent of new wireless applications, and number of video based, internet based application demands for higher data rate integrated communication networks. For that conventionally employed key components are optoelectronic type. However owing to inefficient optoelectronic conversion traditional optoelectronic circuits are deficient to compete with upcoming generations need. Higher data rates could be achieved if the data remained in all optical domains. For that all-optical computing technology is a must need to employ digital optical elements. Accordingly semiconductor optical amplifier (SOA) has been evolved as one of the competent element frequently exercised for amplifying optical signals and for several other functional uses such as wavelength conversion, optical switching, and regeneration, in line amplification and mid span spectral inversion.

In consequence of its low power consumption, low noise, jitter tolerance, compactness, thermal stability that empowers it for the effective utilization in modern optical networks and hence to realize real ultra-high speed vision. As well it cover the potential of being integrated, operationally versatile and the time for buffering / storage could be varied with removing or inserting fiber exclusive of substantial cost in power dissipation or energy loss[1-7]**.** Although semiconductor optical amplifier is a nonlinear element (NLE) reveals strong variation of the refractive index altogether with high gain. Its nonlinear behavior is a downside, though SOA as a linear amplifier composes it an excellent option for an optically controlled gate and let it for photonic integration. Accordingly, for instance SOA's placed as interferometric configurations are compact and present good stability as well provides excellent required performance. Where the input optical signal controls the phase difference in between the interferometer wings linked to the carrier density and refractive index in the semiconductor optical amplifiers through cross phase modulation (XPM)**[**8-10].Implementation of numerous optically controlled logic gates begin primarily near 1992 by exploiting in both glass and semiconductor materials nonlinearities for instance cross absorption modulation (XAM), cross-gain modulation (XGM), four-wave mixing (FWM) and cross-phase modulation (XPM) or permutations of these or with optical amplifier and interferrometric way where input signal were utilized to saturate gain and to modulate a probe wave at the needed output wavelength[11-16]. Numerous designs for all-optical inverter logic operation were explored in the past such as asymmetric semiconductor optical amplifier assisted Mach-Zehnder Interferometer scheme [17], semiconductor optical amplifier loop mirror [18]**.** Consecutively in other study on optical links performance illustrated that modulation formats are too one of the essential factor. As they contribute for the decline of non-linear impact and thus spectral efficiency enhancement for higher data rate optical links. As implementation at higher data rate (>10Gbps) the optical signal-to-noise ratio (OSNR) ought to preferably extend by the matching amount for the bit error rate to be unaltered accordingly modulation formats RZ and NRZ were explored on diverse criteria earlier [19-23]**.**

Accordingly in one of the experimental study for NRZ and RZ format illustrated that RZ format tolerate some linear dispersion compensation, is well supportive for longer link lengths as it is with better receiver sensitivity for a certain launch power, whereas NRZ suffers from nonlinear signal distortion accordingly to devise a NRZ modulation format network creates complexity [24].Whereas performance study for multiple modulation dense wavelength division multiplexed link exhibit better performance for non return to zero raised cosine scheme with quality factor of 16 to 23dB [25].Further study illustrated NRZ is better to RZ for optical systems as restricted by self-phase modulation, amplified spontaneous emission noise, fiber chromatic dispersion and also for duo-binary transmission systems [26].Though altogether with swift growth in design of advanced semiconductor fabrication technology(ASFT) in the preceding era too many efforts have been evolved on towards design of all optical gates but all of them have certain limitations on the performance study for instance data rate, modulation formats and functional optimum parameter analysis. As well in the forthcoming era forever there will be an imperative need for superior performance all optical networks. Accordingly logic gates for optical domain will be one of the fundamental elements so it is a vital objective to propose and investigate for that.

Thus, in this vision a design is proposed for all-optical NOT gate utilizing semiconductor optical amplifier and reflective semiconductor optical amplifier with key benefits of low power consumption, ultra fast, great potential for integration, for that performance is investigated at higher data rate with its numerous key design parameters. The proposed design and through analysis, results and discussion along with conclusion are explored in the subsequent sections.

II. The Proposed Schematic

For the investigations of all-optical inverter operation the designed schematic is illustrated in Fig. 1. Here, the input data pattern is created through continuous wave (CW) lasers, higher power laser is considered as probe signals and other laser source as pump signal generates low power pulses. For the simulation wavelengths 1550nm and 1555 nm have been used. Here the modulator source used can generate NRZ/RZ pulse pattern and the semiconductor optical amplifier (SOA) is used. The semiconductor optical amplifier can be used for normal SOA operation as well as in reflective mode SOA referred as reflective semiconductor optical amplifier (RSOA).

For that the device geometry is such that with input optical signals at one facet and output at another with insignificant facet reflections taken as a traveling wave amplifier. For the reflective SOA (RSOA) mode the output and input optical signals utilize the similar facet, and the opposite facet is arranged extremely reflective and parameter power reflectivity is defined. Here the signals experience two passes all the way through the SOA prior to exiting. Here there are two input ports and one output port. Accordingly one or more optical signals are accepted by first input where as second input accepts an elective electrical modulation current. Subsequently, resulting output optical signal is generated by output port. It makes use of cross gain modulation, for the augment in the input power there is depletion of carriers in the gain region of the semiconductor optical amplifier (SOA) as a consequence there is reduction in the gain of amplifier and the gain acts in tune with the variations in input power on a bit-by-bit basis. Low and high gains are experienced for one and zero bit in the input signal respectively when a low-power probe wave at a different wavelength is injected within semiconductor optical amplifier. An optical filter Fabry Perrot is used to eliminate the high-powered signal in order to avoid counter propagation of pump and probe signal. The key simulation parameters are as explored in the table1. For the necessary measurement subsequently output is employed to BER scope and eye pattern measurement.

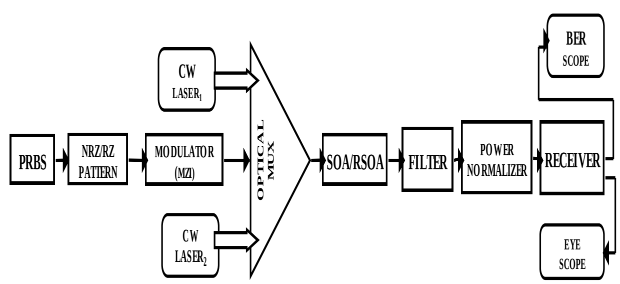

Fig 1. Schematic for optical inverter

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	TABLE-1		
s.n	**Parameter(SOA)**	**value**	**Unit**
1	Confinement factor	1	none
2	Line width enhancement	2.5	none
3	Thickness	1.5e-7	m
4	width	3.0e-6	m
5	Input loss	0	dB
6	Input loss	9	dB
7	Pump current	1	A
8	Length	5e-4	m
9	Reflectivity(RSOA)	1	none

III. RESULTS AND DISCUSSION

In the briskly altering digital era all-optical inverter logic operation is one of the most important functions to realize, as key component of for the all-optical universal logic operations. Accordingly the scheme is designed as shown **(Fig. 1)** to investigate performance of invert (NOT) operation. As invert operation is realized with SOA and RSOA so it is significant to understand the SOA's dynamical performance relating to numerous vital operational parameters. As well as here in the performance investigation ASE (amplifier spontaneous emission) noise and GVD (Group velocity dispersion) is insignificant as pulse propagation unaffected by these factors. The inverter schematic performance is successfully investigated for its numerous key parameters as illustrated in **Fig. (2) To Fig. (10)** bit error rate is plotted against numerous key parameters. The bit error rate is defined as the probability of an error occurring per transported bit, the distributions controlling spread of the lower and upper bars of the eye are given by mean value v_0 and v_1 with width of σ_0 and σ_1 respectively, as expressed in equation1-2.

$$BER = \frac{1}{4}\left[\operatorname{erfc}\left\{\frac{v_1 - v_{level}}{\sigma_1\sqrt{2}}\right\} + \left\{\frac{v_0 - v_{level}}{\sigma_0\sqrt{2}}\right\}, \quad (1)$$

As v_{level} denote the threshold decision level specified as,

$$v_{level} = \frac{v_1\sigma_0 - v_0\sigma_1}{\sigma_0 + \sigma_1} \quad (2)$$

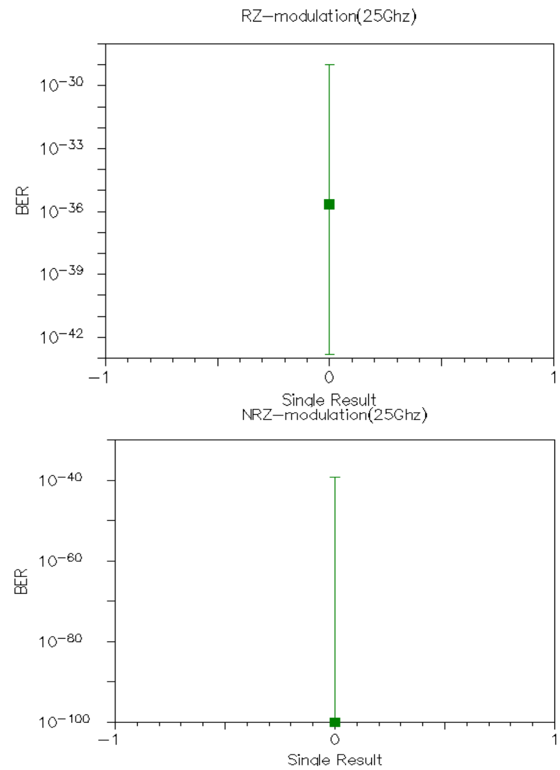

Fig 2. BER plot at 25 GHz data rate for (a) RZ (b) NRZ

Fig.2 depicts investigated bit error rate performance for optical inverter with both NRZ and RZ modulation formats at 25GHz data rate. It is evident that performance with NRZ modulation is better with low down bit error rate, has better dispersion tolerance compared with broader optical bandwidth RZ modulation format which is more influenced by dispersion.

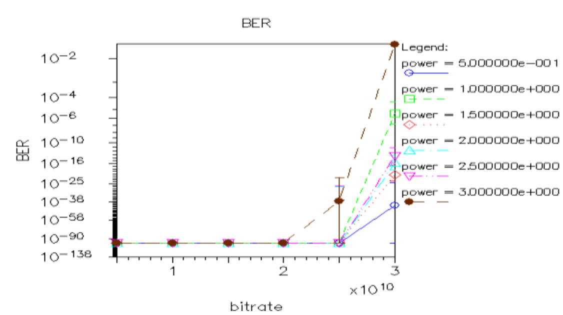

Fig 3. BER vs. bit rate vs. laser power for NRZ (with RSOA)

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Fig.3 depicts investigated bit error rate performance for optical inverter with RSOA for NRZ modulation for variation of bit rate against variation of pump signal laser power. It illustrates that bit error rate lowers at the laser input power of 0.5w whereas performance degrades with hike in laser power.

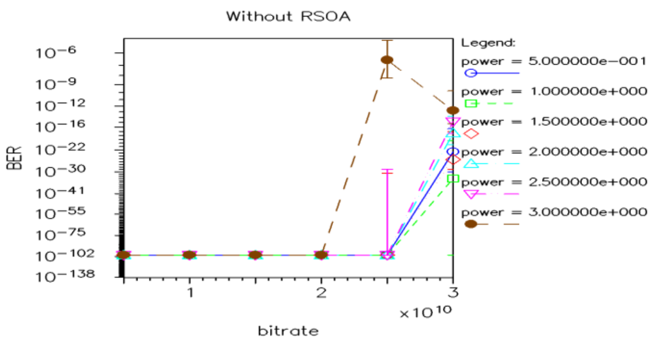

Fig 4. BER vs. bit rate vs. laser power for NRZ (without RSOA)

Fig.4 depicts investigated BER performance for bit rate vs. cw laser power for the optical inverter without RSOA for NRZ modulation. It illustrates that performance degrades without RSOA as bit error rate is high. Though comparing investigated results as demonstrated in the **Fig.3 and Fig.4** it is evident that performance with RSOA is better as bit error rate is low down**.** As in the reflective SOA operation the output and input optical signals utilize the similar facet, and opposite facet is arranged extremely reflective and the signal experience two passes all the way through the SOA prior to exiting.

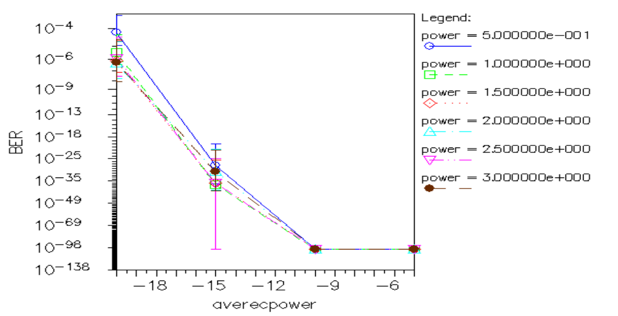

Fig 5. BER vs. averecpower vs. laser power for NRZ (without RSOA)

To observe effect of variation on average normalizer power with laser power on the bit error rate for NRZ modulation without RSOA the simulated results for BER as demonstrated in the Fig.5.

Result depict that performance affected with laser power and show improvement in the links performance accordingly bit error rate low down for the low average attenuator power.

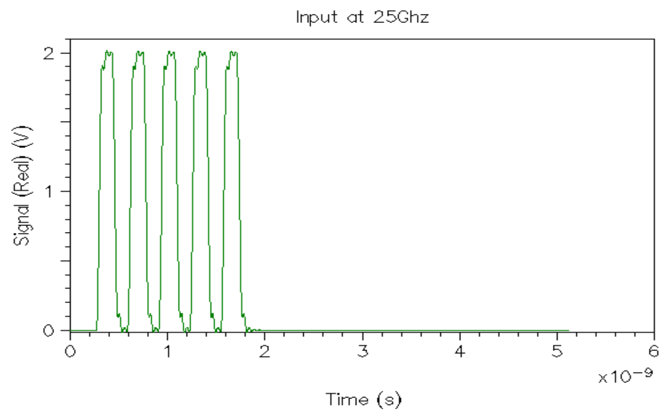

Fig 6. Input [0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 0] pattern

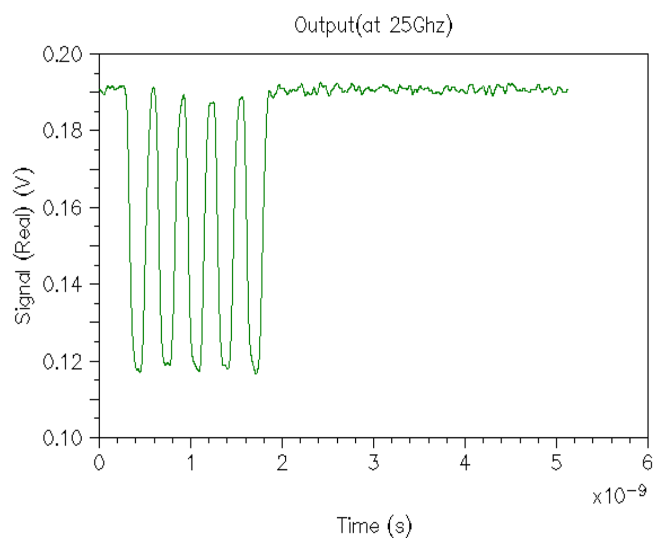

Fig 7. Output Inverted Pattern

The data pattern is generated through continuous wave (CW) laser which are referred to as pump and probe signal.**Fig.6** depicts input bit pattern [0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 0] as implemented for the investigation of inverter operation**.Fig.7** illustrates output pattern corresponding to given input obtained by the simulation. The shown output verifies for the desired invert logic operation.

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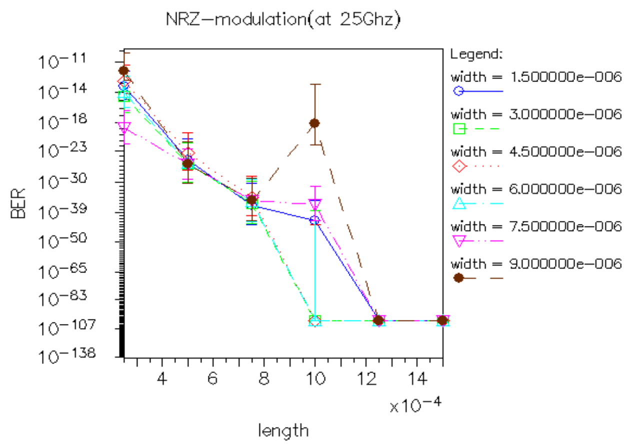

Fig 8. BER vs. RSOA length vs. RSOA width for NRZ

The simulated results for the active length of RSOA and width against bit error rate is as demonstrated in the **Fig.8** for NRZ modulation at 25 GHz data rate. It exhibits that performance is better (low BER) with longer RSOA length and RSOA width.

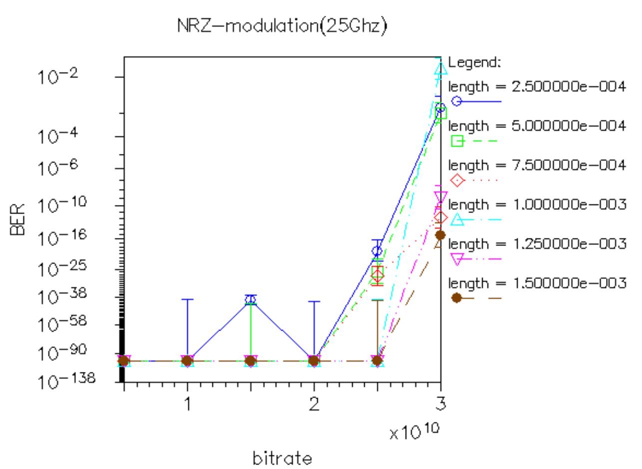

Fig 9. BER vs. bit rate vs. SOA length for NRZ

To observe the effect on bit error rate on the variation of active length of RSOA with NRZ modulation the simulated output as demonstrated in the **Fig.9** for span of data rate 5 to 30 GHz. It reveals that performance is affected with active length of RSOA and bit rate, it improves with increase in RSOA length.

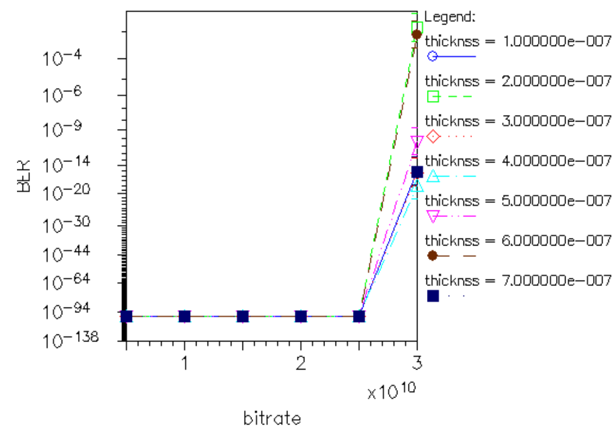

Fig10. BER vs. bit rate vs. SOA thickness for NRZ

With the purpose to view the effect of variation in bit rate and RSOA thickness the simulated results are plotted for bit error rate as against RSOA thickness for NRZ modulation demonstrated in Fig.10. It reveals that performance is as well relying upon bit rate and RSOA thickness. It exhibit good performance with increase of RSOA thickness. Numerous investigations for the injected input bit pattern with key parameters as explored above depicts that optimum performance is subject to selection of the suitably selected key parameters of RSOA for instance its active length, thickness, width, input bit pattern bit rate and the employed modulation format.

IV. CONCLUSION

All optical inverter schematic have been designed and inverter logic operation has been successfully verified. Its performance has been comprehensively analyzed with SOA/RSOA assisted operation. For that numerous numerical simulations have been carried-out with set of key parameters. Results depict that performance NRZ modulation with RSOA showed better performance as compared to RZ modulation. It also depicts that optical links performance is rely upon selection of number of key RSOA parameters. It also exhibits that all optical gates performance is optimum with the appropriate selection of laser power, low average normalizer power, longer SOA active length, SOA thickness and smaller SOA width. Furthermore it also concludes that requisite degree of performance relies upon permutation of numerous key parameters.

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