International Journal of Electronics Engineering (ISSN: 0973-7383)
Volume 11 • Issue 1 pp. 586-591 Jan 2019-June 2019 www.csjournals.com

Enhancement of high speed using Optical Signal processing for optical communication system

Ghanendra Kumar*[a] and Chakresh Kumar[b]
[a]Department of Electronics and Communication Engineering, National Institute of Technology, Delhi-110040, India
[b]University School of Information, Communication & Technology, Guru Gobind Singh IP University, New Delhi
*mail-id: gkumar3c@gmail.com

Abstract –In this paper,a design-model for logic gate operation of AND and OR logic is presented for optical signals only and simulations for the same have been analysed .The realization of these logic gates at high speeds would enable us to upgrade modern communication systems and allow for fast, reliable and efficient optical signal processing in the future. The OR and AND logics are implemented for 40 Gb/s by using EDFAs ,attenuator , optical combiner and high-pass filter. The optical logics are achieved directly by the proposed EDFA-Optical combiner model . The simulations performed make use of optimum and convenient parameters for the EDFA and the optical combiner setup while implementing the logics at 40 Gb/s data rate.

Keywords-EDFA, OSP, BER, NF, quality factor

I-Introduction:-

The optical signal processing is dependent extensively on the network speeds and its efficiency which is affected by the generic optical to electronic conversion and vice-versa .If these conversions are somehow avoided,i.e; all the amplification is done in optical domain itself then the performance of the optical modern communication systems would improve manifold. The use of high speed optical fiber networks has helped connect the world together on the internet and has resulted in a revolutionary growth of science and technology by the human race[1-4].

The advantages of optical communication surpass that of its predecessor i.e, coaxial cable communication as the optical fiber communication systems work easily with lower input power levels, have higher channel capacity and low attenuation factors(dB per kilometer). This advancement improves the efficiency of these processes as the optical to electronic conversions and vice-versa are avoided by using powerful amplifiers which otherwise are quite costly to implement . EDFAs(Erbium Doped Fiber Amplifier) are a much better choice for many optical processing purposes than other varieties of optical amplifiers. Moreover, they are quite affordable for large-scale applications given their longevity[5].

But the high speed optical signal processing still poses certain challenges like attenuation, fiber loss, low quality output, etc. which need to be rectified gradually. Therefore, this study aims at understanding the scope of EDFAs(Erbium-Doped Fiber Amplifiers) for future optical communication systems..We know that to get good fast modes of fiber-optic communication, the power output levels coming from any optical setup must be constructive. The output power needs to be optimized for long distance optical signal communication networks. This study provides an enhanced alternative to optical amplification at high speed of 40Gbps.The designing and simulation of high speed optical logic gates-AND and OR logic gates is done using MATLAB software and the outcomes of the simulations have been discussed[6-10].

II- Working of EDFA:-

Erbium doped Fiber Amplifiers (EDFAs) are currently one of the most reliable amplifiers for optical signals and it is due to their property of low losses .They show a higher gain performance for same wavelength compared to that of the SOA(Semiconductor Optical Amplifier). The operation of an EDFA is based on the principle of amplification in an active medium through feedback mechanism which is, in fact the basic principle of a optical source.It consists of an active medium which is excited by a pump source. The optical input signal to be amplified is then imposed on the active medium via fiber-to-amplifier combiners following which the optical signal gets amplified inside this medium by the phenomenon called stimulated emissions and the output is recoupled to the fiber.The input signal propagates through the active medium and the pump signal power gets transferred to the signal power giving an amplified optical output. Unlike the semiconductor based amplifiers like SOAs, an EDFA is manufactured by doping the core of the optical fiber with Erbium (Er^{3+}) ions which make it useful as a non-optoelectronic converter and the amplification process is done easily with original optical signal.

Effect of stimulated emissions on Gain:-

The incident optical beam falling on the active medium instigates stimulated emission of photons.The pump signal is used to initiate population inversion in the fiber and as soon as population inversion is reached, the input optical signal can go through amplification. Once the stimulated photonic emissions start the number of photons generated by them would suppress the number of photons absorbed by the medium.During the photonic emission process,the erbium(Er^{3+}) ions doped in the medium start making transitions from the metastable energy state to the ground state.The photons create a chain of emissions by influencing more energy exchanges inside the medium and producing stimulated photonic emissions with the same optical phase. After the amplification process through the EDFA ,the output signal is found have significant boost in power and EDFA is known to boost optical signals by upto 30 dB .So,the stimulated photonic emissions provide a useful way of boosting optical signals.But there are certain noise effects to the process as well

III –Noise and Gain specifications of an EDFA-

The proposed logic functions are not ideally implemented .Instead there exist an issue of ASE (Amplified Spontaneous Emissions) noise with the EDFAs as no amplification process is unaffected by random noises. The non-linear characteristic of the active medium cause such distorting effects. However, use of EDFAs is not completely error-free .It has its own disadvantages and there exist some fundamental problems when using EDFAs in an optical network .Some fluctuations occur due to the EDFA saturation which may cause variations in the amplifier's gain and hence affecting the Signal to Noise Ratio of the various light-paths present in the network. Since these light-paths may be destructively interfering each other, the resultant Optical SNR (Signal to noise ratio) may be adversely affected. Thus, the EDFA's non-linearity needs to be balanced by proper parameter selection.

ASE noise:_The major part of EDFA's distorted output comes from the unwanted Amplified Spontaneous Emissions (ASE), whose spectrum is similar to the gain spectrum of the amplifier. The most significant source of distortions in an optical amplifier is due to the undesired spontaneous photonic emissions in the fiber medium. Moreover, the spectrum characteristics of ASE (Amplified Spontaneous Emissions) is found to be broad,i.e ,it covers a significant portion of the optical frequency band. The ASE effects can be mitigated by wise selection of laser source for the generation of optical signals.The power of ASE noise is given as:-

1.) $Power(ase) = 2*nsp/hv(G-1)$;

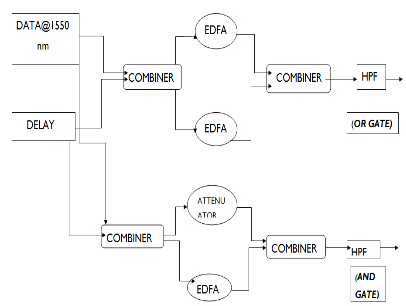
Here,in the above equation ASE power is in milliWatts , G is the amplifier boost ratio , h is the Plank's constant and v is the frequency of incident photonic signal.

By proper alignment of combiners, optical beams can be made to interfere constructively or detructively as and when required. In case of mismatched alignment of beams, there may be distortions in the output spectrum. Misalligned beams result into destructive interference which together with the effect of ASE noise reduce the amplification factor of the EDFA and affect its efficiency.The EDFA gain equation is given as below:

2. $\ln(Gp) = (\ln(Gs) + CS - (Bscp/Bp)) * (Bp/Bs)$; (Bp & Cp are constant, and Bs & *Cs* depend on wavelength.)

IV- Model used and its simulation characteristics-

The EDFA-Optical combiner base setup is as shown in the figure below.The MATLAB software was used to model the communication system implementation by setting proper parameters and implementing them through a proper program.The High Pass Filter at the output ensures that the high frequency amplified optical signal is obtained at the output reducing the effects of low frequency noise.The measure of system performance is the power values for the proposed optical OR gate and optical AND gate model using the EDFAs (Erbium Doped Fiber Amplifier) , optical combiners and attenuators which is obtained by implementation of the normalized power output equation on MATLAB. The output graphs portray the incident optical signal's power vs the final operated output signal power (in milliwatts).**MODEL FOR AND LOGIC AND OR LOGIC FUNCTION USING EDFA-COMBINER SETUP AT 40 GB/S :**

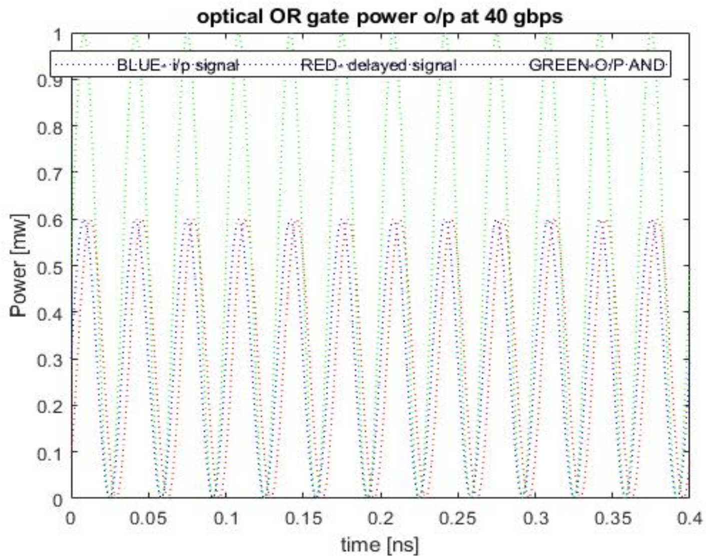


A. <u>Optical OR Gate:</u>-

For the OR logic function using optical signals, we use a 1550 nm optical signal modulated with digital data at 40 Gbps and a delayed version of the same signal.Its power is approximately set at 0.6 mW.Data stream or the digital bitstream used is encoded as RZ signal.The OR logic function is achieved by using a 3 level parallel EDFA-Combiner setup as shown in above figure.By proper use of MATLAB code ,we could find the output power characteristics of this implementation as shown in the figure below.The OR logic function implemented is found to show 0.95 -mW output power. The simulation was carried out and the output was recorded for minute interval of 0.4 ns to avoid any significant delay distortions for larger intervals.The EDFA parameters used for simulations are chosen such that it provide optimal performance keeping in mind the ASE noise issue and other distortions. The OR logic function of

International Journal of Electronics Engineering (ISSN: 0973-7383)
Volume 11 • Issue 1 pp. 586-591 Jan 2019-June 2019 www.csjournals.com

the optical signal with its phase delayed version(delayed by pi/4 radians)is successfully implemented.

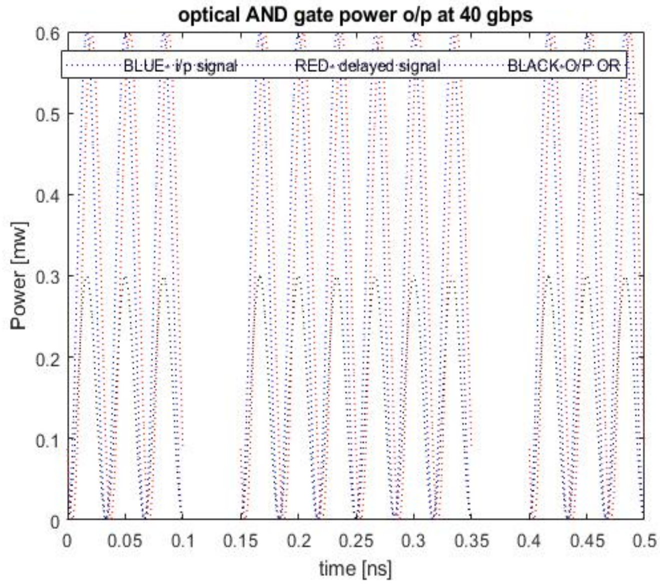


Optical OR gate power o/p

B. Optical AND Gate;-

For the AND logic function using optical signals, we use a 1550 nm optical signal modulated with digital data at 40 Gbps and a delayed version of the same signal.Its power is approximately found to be 0.6 mW.The proposed AND logic function setup uses an attenuator (a low gain amplifier) after the first optical-combiner stage in parallel to the EDFA so as to allow significant functioning of the AND logic operation followed by another optical combiner for mixing of the EDFA output and the Attenuator output.By proper use of MATLAB code we could find the output power characteristics of this implementation as shown in the figure below.For the AND logic as well,the EDFA parameters are chosen so as to minimize distortional effects in the implementation. This AND logic gives 0.29 -mW output power for input signals of 0.60 mW power.The simulation was carried out for short period of 0.5 ns as the proposed setup could give smooth results for smaller durations without causing any significant delay distortions.The AND logic function of the optical signal with its phase delayed version(delayed by pi/4 radians)is successfully implemented.

IJEE 0973-7383
International Journal of Electronics Engineering (ISSN: 0973-7383)
Volume 11 • Issue 1 pp. 586-591 Jan 2019-June 2019 www.csjournals.com



Optical AND gate power o/p

V- CONCLUSION:-

The proper implementation of the EDFA-Combiner setup on MATLAB provides desirable output for both optical AND gate and OR gate purpose.The power characteristics of the outputs signals in both the cases shoe enhanced results as compared to the existing results of semiconductor-based amplifier and opto-coupler setups.The output characteristics for the logic functions implemented give better result and pave the way for significant enhancements in modern optical communication systems and for faster future networks.The simulation of the AND and OR logic functions is performed for minute intervals at the digital data speed of 40Gbps.These results are obtained in accordance with the expectations and the output signal power obtained for both the AND logic gate and OR logic gate are found to be quite satisfactory. These results show promising enhancements for ultra-fast optical signal processing for modern and future communication systems.

VI- REFERENCES:-

1. S. Singh and Lovkesh, "Ultrahigh Speed Optical Signal Processing Logic Based on an SOA-MZI," in IEEE Journal of Selected Topics in Quantum Electronics, vol. 18, no. 2, pp. 970-977, March-April 2012.

2. Singh, Surinder & Kaler, R S. (2007). Analysis and minimization of cross phase modulation in semiconductor optical amplifiers for multichannel WDM optical communication systems. Optics Communications. 274. 105-115. 10.1016/j.optcom.2007.02.007.

3. O'Mahony, M. J. 1988. Semiconductor laser optical amplifiers for use in future fiber systems. J. Light. Technol., 6: 531–544.

4. I. Kang, M. Rasras, L. Buhl, M. Dinu, S. Cabot, M. Cappuzzo, L. T. Gomez, Y. F. Chen, S. S. Patel, N. Dutta, A. Piccirilli, J.Jaques, C. R. Giles, "All-optical XOR and XNOR operations at 86.4 Gb/S using a pair of

semiconductor optical amplifier Mach–Zehnder interferometers", *J. Opt. Exp.*, vol. 17, no. 21, pp. 19062-19066, Oct. 2009.

5. Z Pinter, Stephen. (2019). EDFA SIMULINK MODEL FOR ANALYZING GAIN SPECTRUM AND ASE.

6. I. Kaminow and T. Li, Optical Fiber Communication IVA, Academic Press, 2002.

7. M. Sahafi, A. Rostami, and A. Sahafi, “All-optical high speed logic gates using SOA,” *Optics Communications*, vol. 285, pp. 2289–2292, 2012.

8. R. P. Webb, X. Yang, R. J. Manning, and R. Giller, “All-optical 40Gbit/s XOR gate with dual ultrafast nonlinear interferometer,” Electronics Letters, vol. 41, pp. 1396–1397, 2005.

9. Bebawi, John & Kandas, Ishac & A. El-Osairy, Mohamed & Aly, Moustafa. (2018). A Comprehensive Study on EDFA Characteristics: Temperature Impact. Applied Sciences. 8. 1640. 10.3390/app8091640.

10. B. Bouzid, "Analysis and review of Erbium doped fiber amplifier," *2013 Saudi International Electronics, Communications and Photonics Conference*, Fira, 2013, pp. 1-5. doi: 10.1109/SIECPC.2013.6551005