Improvisation of Gain and Bit-Error Rate for an EDFA-WDM System using Different Filters

Sharmila M
M.Tech LEOE
Department of physics
College of engineering guindy
Chennai 600025
India.

N Victorjaya
Professor
Department of physics
College of Engineering Guindy
Chennai 600025
India.

Abstract: **The Gain flatness of EDFA plays an important role for Wavelength Division Multiplexing (WDM) optical application. Equalizing of an amplifier's gain spectrum is essential for balancing the channel powers to achieve error free detection of the signals transmitted through the optical link. The purpose of this paper is to improve the gain unevenness for each channel in order to equalize the amplitude in a Wavelength Division Multiplexing (WDM) system. And also various filters have been taken under study to find its effect on the output. The design simulation aided by Optisystem 12 software. From the analysis it has been found that the gain flatness is improved by optimizing the pump power, pump wavelength and fiber length. The optimized value of EDFA to achieve maximum gain flatness under different filters are presented. The gain are flattened within 32.75dB-33.67dB from 1546 nm-1558 nm band of wavelength with noise figure (NF) < 7dB, output power 15 dB, Bit Error Rate (BER) <** 10^{-22} **& Quality factor is 14.64. By these above parameters, gain flatness of 0.3dB can be achievable.**

Keywords: WDM, EDFA, filters, gain flatness, fiber length, pump power.

INTRODUCTION

Erbium Doped Fiber Amplifier, commonly known as EDFA is an attractive optical amplifier in optical applications which uses a doped optical fiber to amplify optical signal for a gain medium. The optical gain from a fiber amplifier still can affect System performance by its dependence on wavelength (1). EDFA has certain special features like low noise, large bandwidth, small splice loss and high gain. EDFA which advanced the optical fibre communication by overcoming the propagation losses are very useful in wavelength division multiplexing, by providing uniform gain over wide range of wavelengths (2). EDFA having greater bandwidth in the range of tens of nanometers is adequate to amplify data channels at high rate having lack of gain narrowing (3). Interaction of the doping ions takes place when pump power and the signal to be amplified are multiplexed. EDFA is most frequently used for optical amplification suited for silica based fibers having minimum loss. (4)

WDM system is difficult to implement because of the dependent on wavelength of EDFA gain spectrum and it does not amplify the wavelength equally (5). Although EDFA systems are still needed to have equalized gain spectrum order to obtain similar signal to noise ratio and uniform output power (6). Various methods are there in designing a flat spectral gain of EFDA, by controlling the pumping power and length of fibre (7), by using a proper notch filter, or by acousto-optic tunable filter (8). Flatness can be improved by tuning aperture of low pass filter by controlling fibre length and pump power (9). In this paper the gain flatness is obtained by controlling the length of doped fibre and pumping power and bit error rate is controlled by using filter.

This paper is organized in such a way following the introduction in chapter 1, Filters taken for study are discussed in second chapter, Architecture in third chapter Schematics discussed in fourth chapter. Results and discussion in chapter fifth and conclusion in the last chapter.

II. FILTERS

Low pass filters which can pass the components in both electrical and optical domain used as demodulators or receivers. As modulating the data before sending through the medium by carrier frequency i.e, laser frequency so that modulated data have high frequency. Hence it becomes necessary to demodulate into low frequency. For better receiving of signal at reception, low pass filters are used. This filters which capable of removing noises that entered into system usually at high frequencies. The low pass filters taken are Chebyshev, Raised Cosine and Butterworth filter.

A raised cosine filter which is commonly used for pulse shaping in data transmission systems because of its ability to minimise Intersymbol interference. A perfect raised cosine filter will have a frequency response $|H(f)|$ is symmetrical about 0 Hz. Three parts it is divided into are flat in pass band; outside the band it is zero; Chebyshev filters may be digital or analog filters having more passband ripple or steeper roll-off or stopband ripple than the Butterworth filter. With the ripples in the pass band, chebyshev can minimize the error between actual and idealized filter (6). Pass band ripple inheritance in chebyshev have a smoother response in pass band and irregular response in stop band are preferable for few applications. Butterworth, first and best filter known for the approximation have maximally - flat response. Having a flat pass band with no ripple and reasonably good phase response. Roll off is monotonic and smooth with high/low pass roll rate of 20 dB/decade/pole.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

I. ARCHITECTURE

Simulation based work is done rather than fabrication, because of the advantage the modern simulation software's provide. Efficient and accurate design can be obtained using the simulation software's and more problems can be studied while designing the optical network. Optisystem by Optiwave is a comprehensive package enables the users to plan and tests moreover simulate the optical networks.

The system design as shown in fig 1 consists of 16-channel WDM transmitter, 3R generator, low pass chebyshev filter, erbium doped fiber, photo detector, WDM demultiplexer and ideal multiplexer. Using various and differentiated values of above mentioned parameters better values of bit error rate, gain flatness and quality factor are obtained. For this system design 16-channel WDM transmitter from the wavelength 1546 nm-1558 nm is used. Keeping frequency spacing between channels as 0.8 nm and power pump is -23dBm and by adjusting the pump power and fiber length

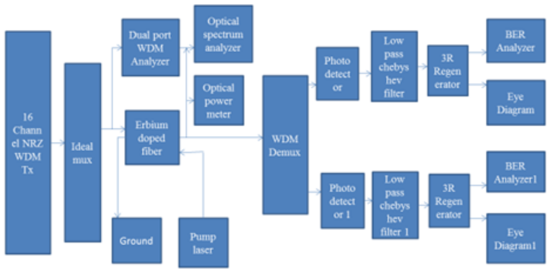

Fig 1.1 Schematic design of EDFA in WDM system

Various results have been obtained. Also keeping pump power constant and varying the fiber length, gain flatness and noise figure were analyzed.

II. SCHEMATICS

The schematic diagram for the three filters with following specifications are given accordingly. Fig 1.2 shows the schematic design of EDFA in WDM system with Chebyshev filter. For low pass Chebyshev filter, the system consists of 16 input channels (signals), demultiplexer, pump laser, Photo detector PIN, ideal multiplexer, Erbium doped fiber, 3R generator and low pass chebyshev filter with the following Specifications:

1. For WDM Transmitter:
   Input power = -26 dBm
   Frequency = 1546-1558 nm
   Modulation Type = NRZ
   Frequency spacing = 0.8 nm
2. Erbium Doped Fiber Length = 7.1m
3. Pump Laser:
   Frequency = 980 nm
   Power = 120 mW
4. Low Pass chebyshev Filter:
   Cut off frequency = 0.99*Bit Rate Hz

The Optical Power Meter measures the output power whereas Dual Port WDM Analyzer measures gain flatness.

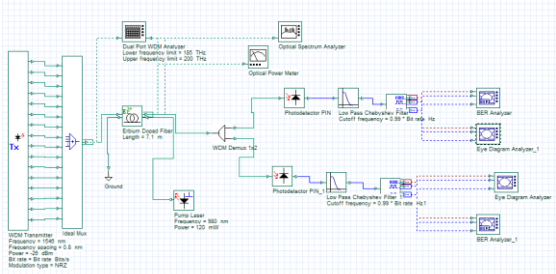

Fig 1.2 Schematic design of EDFA in WDM system with Chebyshev filter

Fig 1.3 shows the schematic design of the EDFA in WDM system with low pass cosine filter.

1. For WDM Transmitter:
   Input power = -23dBm
   Frequency = 1546-1558 nm
   Modulation Type = NRZ
   Frequency spacing = 0.8 nm

2. Erbium Doped Fiber Length = 6.7m

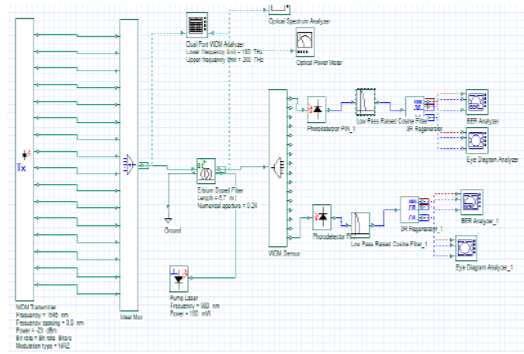

Fig 1.3 Schematic design of EDFA in WDM system with low pass cosine filter.

3. Pump Laser:
   Frequency = 980 nm
   Power = 150 mW
4. Low Pass Raised cosine Filter:
   Roll off factor=0.5

Fig 1.4 shows the schematic design of the EDFA in WDM system with Butterworth filter.

1. For WDM Transmitter:
   Input power = -23dBm
   Frequency = 1546-1558 nm
   Modulation Type = NRZ
   Frequency spacing = 0.8 nm
2. Erbium Doped Fiber Length = 6.7m
3. Pump Laser:
   Frequency = 980 nm
   Power = 150 mW
4. Low Pass Butterworth Filter:
   Cut off frequency = 0.75*Bit Rate Hz

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

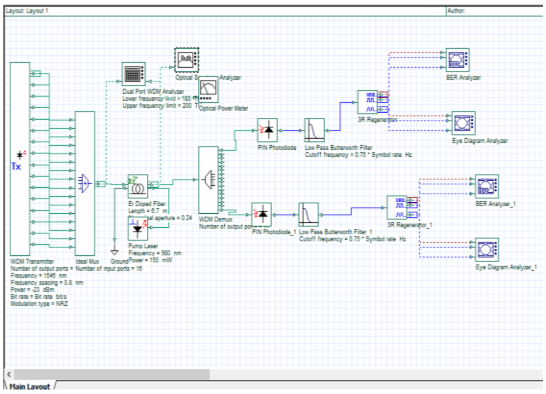

Fig 1.4 Schematic design of EDFA in WDM system with Butterworth filters.

III. RESULTS AND DISCUSSIONS

By doing simulation for the Chebyshev filter first, it is observed that by varying the pump power for different fiber length at a constant input power (-26dBm). The output power increases with the increase in pump power which is shown in fig 1.5. For a given input power the output power increased initially then after the gradual decreasing it gets saturated up to length it's improved. For the given pump power 100 mW, the gain high 33.75dB with low noise figure 4.724dB attained but in this case the gain flatness is 2.065dB because it is not equalized for all channel. For the given pump power 250mW the gain flatness is also less 1.32dB with higher gain 37.5632dB but also the noise figure is very high 8.62dB. For EDFA-WDM system is concerned high gain flatness is not good. From the analysis, there is no equalized gain for all channels when the pump power is 100mW and 250mW causing poor performance. The optimized value is obtained for fiber length 7.1m and 120mW pump power the gain flatness is 0.38 with noise figure 6.9dB.

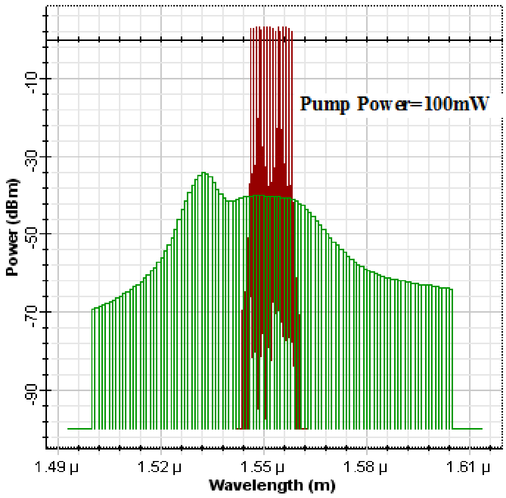

Fig 1.5 Output power (red) and Noise power (green) at 100mW

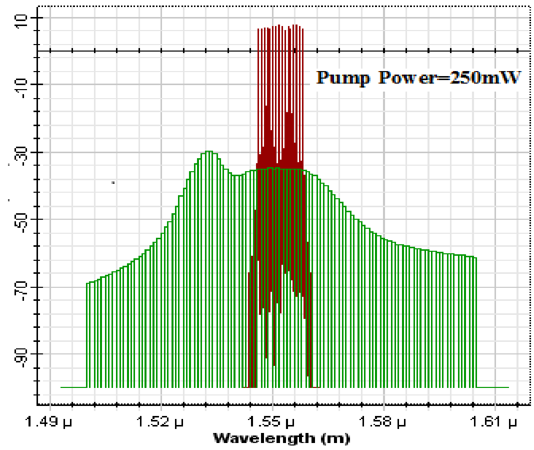

Fig 1.6 Output power (red) and Noise power (green) at 250mW

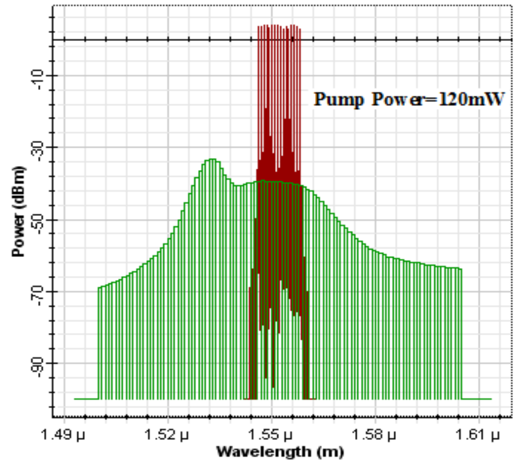

Fig 1.7 Output power (red) and Noise power (green) at 120mW

Simulation results for Low pass cosine filter obtained as by keeping power pump is -23dBm and the frequency spacing between channels as 0.8 nm. By adjusting the pump power and fiber length various results are obtained. By keeping the pump power constant (-23dBm) and adjusting fiber length analyzed noise figure and gain flatness.

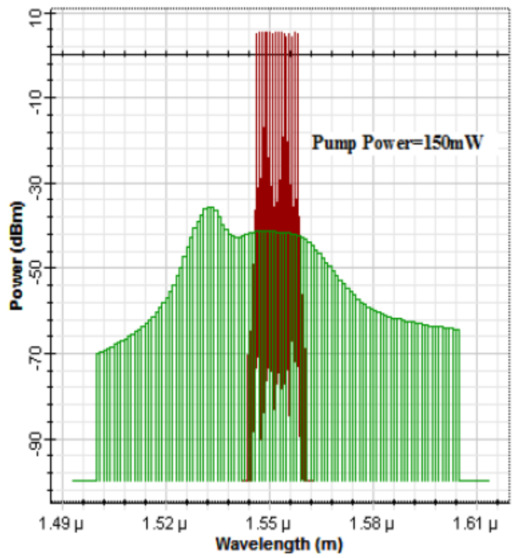

Fig 1.8 Output power (red) and Noise power (green) at 150mW

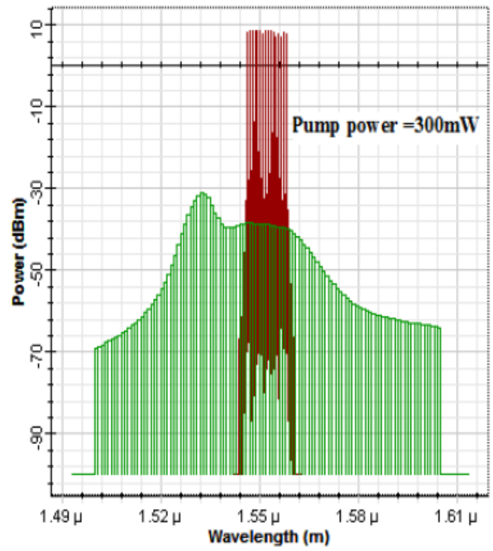

Fig 1.9 Output power (red) and Noise power (green) at 300mW

For a given fiber length of 4m and pump power of 150 mW the gain flatness is within 31.68dB-29.24dB which is 2.45dB and noise figure obtained is 3.48 dB and bit error rate is nearly of 10^{-11}. Although for the mentioned parameters, got better bit-error rate with very low noise figure but the gain flatness is high (Since our desired flatness is < 0.5dB). For the pump power being 150 mW and fiber length 10 m we achieved the gain flatness of 3.648dB and noise figure of 12.27dB and bit error rate as 10^{-8}. The results do not deserve, by keeping the length of fiber constant and varying the power the results are analyzed.

For and fiber length 6.7m and pump power 300mW, gain flatness are within 35.563dB- 34.62dB (0.63dB) with noise figure 5.96dB. Since noise figure is low and gain is high the gain flatness is high. From the analysis, the optimized values are measured at pump power 150mW and fiber length 6.7m for EDFA system with numerical aperture 0.24.

ANALYSIS OF BIT ERROR RATE

By BER (Bit Error Rate) analyzer, system performance is analyzed and the graph of minimum BER for channel shown in figure 1.8**.** Using low pass raised cosine filter with roll off factor of 0.5 wide opening of eye diagram gives is obtained shows the low inter symbol interference (ISI).

Eye-diagram opening width indicates sampling time over which the sampling detection performed. The The maximum eye opening provides greatest protection against noise. Average noise figure of 6dB and output power 19 dBm obtained with good BER performance in the range of 10^{-10} to $10^{-11}$for WDM system. And also with quality factor 6.

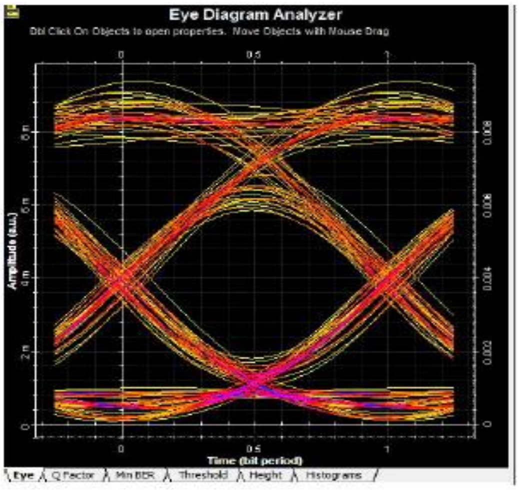

Fig 1.10 Eye pattern of the system

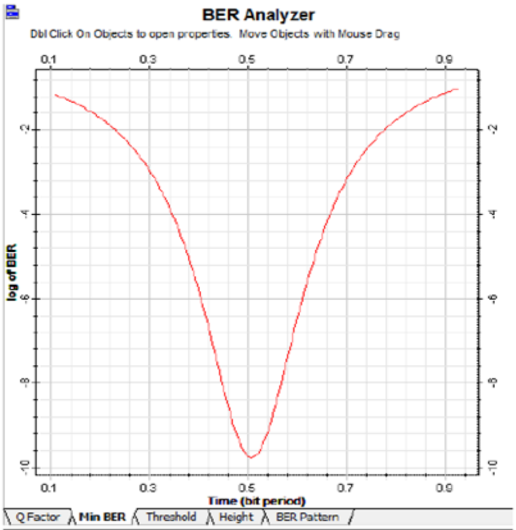

Fig 1.11 Graph of min BER

For this study two low pass chebyshev filter with ripple factor 0.5dB is used .The BER is in the range of 〖10〗^(-21). For pump power 120mW, fiber length 7.1m, numerical aperture 0.24 and BER having quality factor 14.7808.The graph of quality factor shown in figure 1.12.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

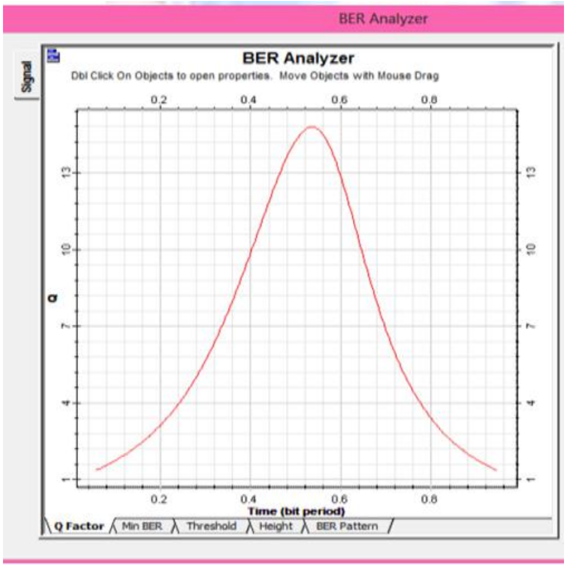

Fig 1.12 Graph for quality factor

By interpreting the eye diagram analyzer, the eye pattern with a big eye opening mean, the low inter symbol interference (ISI) and with average BER is 10^{-22} for chebyshev filter with ripple factor 0.5dB.And for EDFA in WDM system with Butterworth filter the performance are quite low with poor roll off rate, slower execution speed and exhibits a flat pass band with no ripple. Even though Butterworth filter used for anti-aliasing application purpose, Chebyshev are preferred where frequency content of signal is more important than constant amplitude.

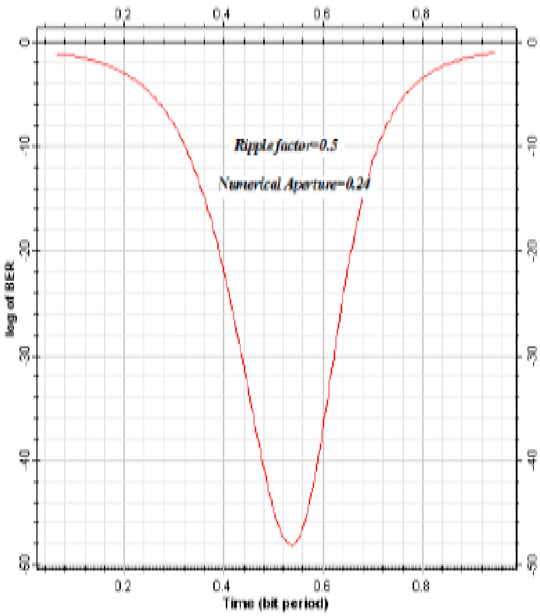

Fig 1.13 Improved BER

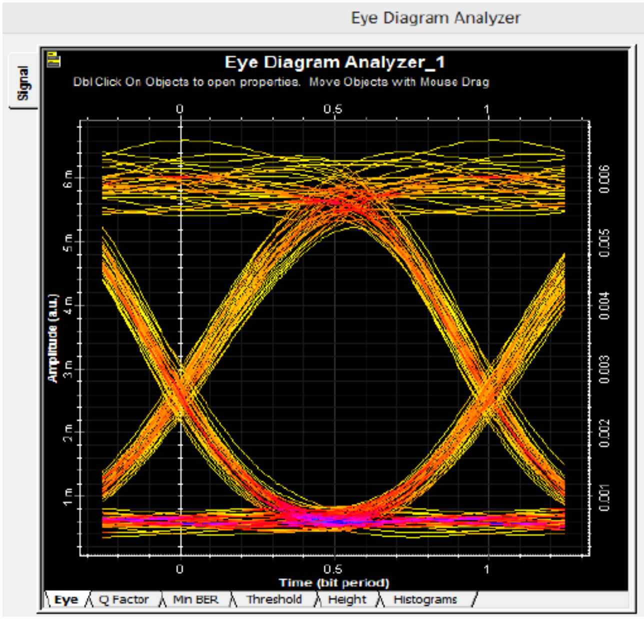

Fig 1.14 Eye pattern of the system

IV. CONCLUSION AND FUTURE SCOPE

The EDFA based WDM system is analyzed for optimization with the use of simulation software. By varying the input power, fiber length and pump power for each of the filter in WDM system, optimized values are obtained with desirable low noise figure, high gain, low bit rate error. And in comparing the three filters Chebyshev is a better one. The gain are flattened within 32.75dB-33.67dB from 1546 nm-1558 nm band of wavelength with noise figure (NF) < 7dB, output power 15 dB, Bit Error Rate (BER) < 10^{-22} & Quality factor is 14.64. By these above parameters, gain flatness is 0.3dB is achieved.This study has been carried out with Chebyshev, Butterworth and low-pass cosine filter in the EDFA based WDM system with the intention of analyzing the effect of input parameters to improvise gain and bit error rate. In future, the analysis will include more filters for the study to improvise bit error rate and gain.

REFERENCES

[1] Farah Diana Binti Mahad, Abu Sahmah Bin Mohd Supa'at, "EDFA Gain Optimization for WDM System", Faculty of Electrical Engineering University Technology Malaysia, ELEKTRIKA, VOL. 11, NO. 1, 2009.

[2] C.R. Giles, E. Desurvire, Modelling erbium-doped fiber amplifiers, J. Light wave Tech. vol.9, pp. 271– 283,1991.

[3] Abu Sahmah Supa'at and Farah Diana Mahad, "EDFA Gain Optimization for WDM System," ELEKTRIKA, vol. 11, no. 1, pp. 34 37, 2009.

[4] Honde, V., Mhatre, A., Tonde, S., Barkul, S., & Pund, P. Performance Analysis of WDM Network Based On EDFA Amplifier with Different Pumping Techniques.

[5] Y. Sun, A. K. Srivastava, J. Zhou, and J. W. Sulhoff, "Optical fibre amplifiers for WDM optical networks", *Bell Labs. Tech. J.*, vol. 4, pp.187-206, 1999.

[6] Surinder Singh a, R. S. Kaler, "Gain flattening approach to physical EDFA for 16 × 40 Gb/s NRZDPSK WDM optical communication systems", *Fiber and Integrated Optics*, vol. 25, Issue 5, pp. 363-374, 2006.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

[7] Verma, D., & Meena, S. (2014, November). Revitalization of Gain Flatness and Bit-Error Rate for an EDFA-WDM System. In *Computational Intelligence and Communication Networks (CICN), 2014 International Conference on* (pp. 237-241). IEEE.

[8] Usman J Sindhi, Rohit B Patel, Kinjal A Mehta, Vivekananda Mishra "Performance Analysis Of 32-Channel Wdm System Using Erbium Doped Fiber amplifier", ISSN 2319 – 2518 Vol. 2, No. 2, April 2013 © 2013 IJEETC.

[9] Verma, D., & Meena, S. (2014). Gain Flatness and Bit Error Rate Improvements for an EDFA in WDM System. *International Journal of Enhanced Research in Science Technology & Engineering*, *3*(5), 408-412.