International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 10, October-2015

# Optimized Flattened Gain Spectrum in C –Band WDM using Automatic Gain Control in Bi-Directionally Pumped EDFA

[1]V. S. Lavanya*, [2]V. K. Vaidyan
[1,2]Department of Physics,
Mar Ivanios College, Thiruvananthapuram,
Kerala- 695015

***Abstract*: In most of the telecommunication requirements, information needs to be carried at a long distance more than hundreds of kilometre and where the need of optical amplifier comes into picture to compensate mainly for the attenuation losses. Advancement in WDM and DWDM techniques enable the co-propagation of signals of different wavelength, thereby achieving data transmission speed as high as hundreds of gigabit per second over thousands of kilometre in a single mode fibre with most suitable optical amplifiers [1]. Erbium Doped Fiber Amplifiers have evolved as the most preferred optical amplifier and are widely used due to its transient suppression, wide band variable gain operation and also because of the low losses, amplification window where fiber has useable gain, high power transfer efficiency, large dynamic range, low noise figure etc. [2]. But, amplifier gain variations is an important concern in WDM networks, because the signal power fluctuations can be severe as the number of channel increases and the gain depends on the transmitted power. EDFA typically operated in two different modes viz. APC (Automatic power Control) and AGC (Automatic Gain Control), but, AGC method is mostly used in multi-channel WDM applications [3]. Several techniques were reported for the EDFA gain equalization, like, Thin film filters, long period fiber gratings, chirped fiber Bragg gratings etc[4]. There are different approaches being studied for automatic gain control in EDFA[5-8]. In this paper, we attempted one such automatic gain control technique to achieve an optimized flattened gain with very low noise figure with the help of numerical methods. The maximum value of the gain is 24.85 dB with a gain tilt of 1.65 dB, which is a very promising result since optical gain greater than 20 DB is very useful in WDM applications, with the advantage of having a flattened spectrum.**

***Keywords: Erbium Doped Fiber Amplifier (EDFA), artificial neural network (ANN), Wavelength Division Multiplexing (WDM), Automatic Gain Control (AGC), Mean Square Error (MSE), signal to noise ratio (SNR).***

## 1. INTRODUCTION

Long distance transmission of optical signals faces two major challenges viz. dispersion and attenuation. Several techniques have been adopted for overcoming these limitations of fiber optic communication system. Dispersion Compensated Fibres (DCF) and introduction of optical amplifiers respectively facilitated the evolution of high speed long haul communication using fiber optics. It has made a revolutionary change in telecommunication especially for the large volume of data transmission like real time video. So, optimization of optical amplifiers can improve the information carrying capacity and maximize the bandwidth utilization of the channel. There are various kinds of optical amplifiers being used in the communication system based on the requirements and characteristics of the amplifier. Out of these, Erbium doped Fiber Amplifier is extensively used because of its compatibility with optical fiber and also for its low insertion loss, low cross talk, high gain, polarization insensitive and low noise figure. Also, an EDFA has a comparatively wide range of amplification making it primarily useful as transmission amplifier in wavelength division multiplexing systems [9-13].Theoretically, EDFA is capable of amplifying all the wavelength ranging from 1500 to 1600 nm. However, practically there are two windows of wavelength, C band and L band [14]

Wavelength-division multiplexing (WDM) is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths of laser light. This technique enables bidirectional communications over one strand of fiber, as well as multiplication of capacity. WDM systems received wide popularity with telecom companies because it allows to expand the capacity of the network without laying more fiber. With suitable selection of optical amplifier and its parameters, along with WDM technology, such systems can accommodate several generations of technology development in the optical infrastructure without having to overhaul the backbone network.[15,16] Capacity of a given link can be expanded simply by upgrading the multiplexers and de-multiplexers.

The key difficulty in using a conventional EDFA in such systems is that the gain spectrum on an EDFA is not constant over the bandwidth .The non-uniformity of gain in an EDFA--which has little impact on single-channel transmission--becomes a strong limitation with multiple channels. The accumulation of gain discrepancies results in a level discrepancy and a signal-to-noise ratio (SNR) discrepancy, with a significant bit error rate (BER) penalty for the worst channels. Another limitation to the easy integration of EDFAs in WDM transmission lines is the gain variation with total input power [17]. In those systems, optical power per channel is usually constant at the input of an EDFA, but the overall number of channels propagating through the amplifier may vary. In that case, adding or dropping some channels will have a strong impact on the gain available for the other channels.

Gain fluctuations at the receiver side in long distance communication using WDM channels have severe impact on exploiting the transmission capacity and bandwidth capability of fibre optic communication system. The need for stabilizing the gain, based on various requirements, is fully understood by the researchers and tremendous effort is being put towards controlling the variations. Most of such effort was adopting different techniques which uses various optical elements. Some others worked on automatically controlling the variations [18, 19]. We discuss one such approach to automatically control the gain fluctuations by using bidirectional pumping of EDFA to achieve an optimized value of gain in C –band, which will help to push the bit rate and transmission distance higher and higher.

## 2. EXPERIMENTAL SET UP

Fig. 1 shows the experimental setup of the proposed transmission system with bi-directionally pumped EDFA. The input 32-channel WDM signals, located over 1537.7 nm to 1562.5 nm, were generated by a WDM transmitter with bandwidth of 30 GHz and frequency spacing of 100 GHz with NRZ modulation type. 32*10Gbps NRZ format modulated signals are multiplexed and transferred through single mode fiber. The signals are affected by three loss factors during the transmission viz. attenuation, dispersion and non-linearity. The non-linearity is eliminated by maintaining each channel input power below certain value. Dispersion is nothing but wavelength dependent refractive index and the respective pulse broadening behaviour. This will create Inter symbol Interference (ISI) in the receiver. Attenuation is another impact factor, which will limit the transmitted power in the optical fiber. After a certain distance, the signal couldn't be with the required power level in order to retrieve the original signal. For the better transmission and reception within allowed BER. We have to compensate these limitations, what are discussed so far. As already stated, non-linearity is overcome by maintaining the minimum input power. Attenuation is compensated by introduction of the amplifier in the channel; dispersion is compensated by DCF fiber with negative dispersion next to the single mode fiber. Normally all optical amplifier is preferred compared to O/E/O technique to overcome the problems associated with it. As shown in the figure 1, the multiplexed signal is transferred through a single mode fiber over certain distance and then the attenuated signal is amplified by EDFA. The accumulated dispersion of the signal is compensated by DCF, and the attenuation introduced by DCF is compensated by the second EDFA. Finally, attenuation and dispersion compensated signal is recovered at the receiver. As we mentioned, fiber with rare earth doped element such as Erbium, Thallium, Ytterbium used for all optical amplification. Particularly, Erbium doped fiber amplifier is promising one, because it's having the energy band in the currently deployed optical communication C band. Normally, EDFA having unequal gain spectrum over the C band as in figure 2, but it should be flattened in order to preserve the Quality of service for the operated 32 channels. In this work, we focus to generate an optimized flattened gain spectrum in C-band using bidirectional pumping scheme. Out of different pumping schemes, bi-directional pumping has proved the best way of achieving high power amplification with a moderate noise level, using single core EDF [20]

A pump laser of frequency 980 nm and pump power of 68 mW is used for co –propagating pump and frequency of 975 nm and 100 mW is used for counter-propagation. A single mode fiber of 100 km is used as the channel for transmission. An EDFA of length 5m is used to compensate the attenuation and DCF is used

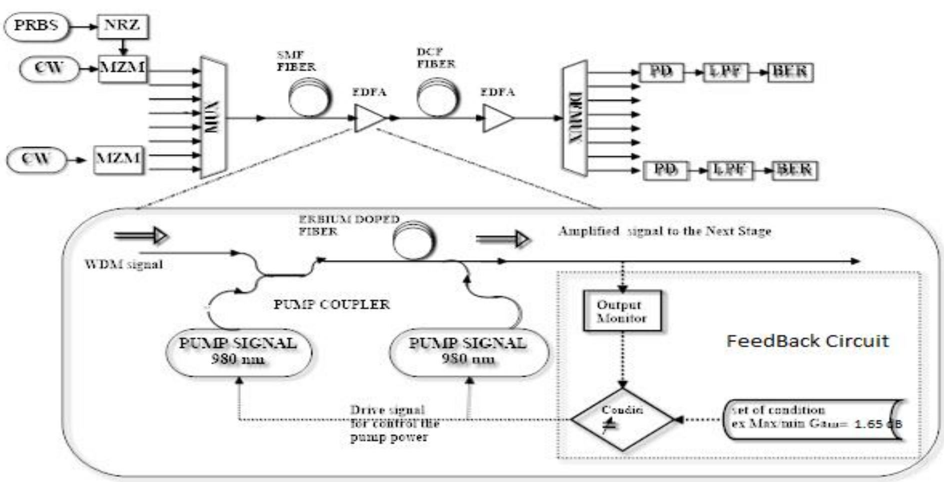


Fig1 Optical Communication system with bi-directionally pumped, gain controlled EDFA

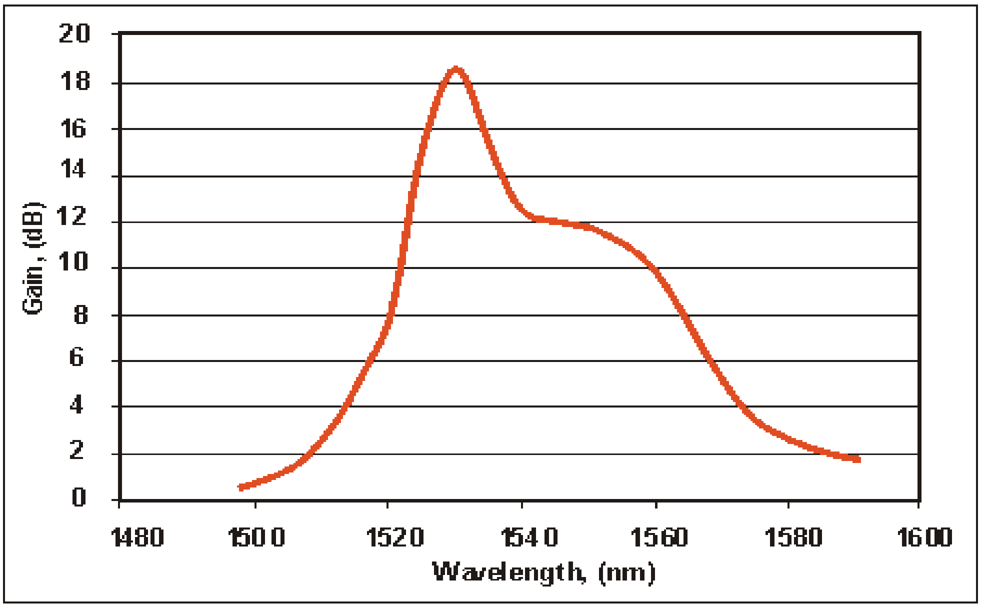


Figure 2 Normal EDFA Gain Spectrum

in the channel for nullifying the dispersion factor. The EDFA has a core-radius of 2.2 µm and Er3+ density of $10^{24}$ $m^{-3}$. At the receiver side, the optical signals are received and the quality of the received transmitted signal is well studied.

## 3. RESULTS AND DISCUSSION

In the present study, the transmission system is designed in such a way that a flattened spectrum is received at the receiver side since gain fluctuations will adversely affect the quality of transmission. Figure 6 shows the gain spectrum for 32- channel WDM transmission with bi-directionally pumped EDFA. The maximum value of the gain is 24.85 dB with a gain tilt of 1.65 dB. That means, the ratio of maximum to minimum value of the gain between the channels is only 1.65 dB, which is a very promising result since a gain tilt less than 3 dB is considered as a flattened gain in optical communication system [21]. Also, relative flat gain greater than 20 dB is appreciated in WDM applications. A good comparison with the normal EDFA gain spectrum as in figure 2 envisages the performance improvement in the proposed system. The maximum value of the noise figure in the system is 3.85 dB and varies between 3.3 dB to 3.4 dB at much flattened gain. The value of the noise figure would always be greater than 1, and quantum mechanics puts a lower limit of 3 dB to optical noise figure at high optical gain [22]. So, with the current configuration of the system yields a very promising result for good quality reception with flattened gain. Figure 4 shows the noise figure of the proposed WDM system. The output noise spectrum is also shown in figure 5, the noise power is maintained in the range of -30 dbm or below, which ensures a better signal-to-noise ratio (SNR) and a transmission quality. The Bit Error Rate (BER) directly depends on the optical noise parameters. The minimum value of output optical SNR received is 34.34 dB with a maximum value of 35.14 dB. As shown in figure 1, a feedback circuitry with set of conditions embedded is used to control the pump powers so that the output stays within the desired range. Such results can be used to model an EDFA which will predict the behaviour of the system under different configurations. The advantage here is not only a flattened spectrum, but, a good gain too.

Here, the launching input signal power to the EDFA is maintained at -19dBm, and, the minimum value of the output power of the channel is 3.41 dBm with a maximum value of 5.11 enabling a smooth balanced performance. This helps to keep the good receiver sensitivity and maintain a good SNR as explained earlier. The power output spectrum of the communication system received using bi-directionally pumped EDFA is shown in figure 3. The less variations in the received power denotes a flattened spectrum, which is desired.

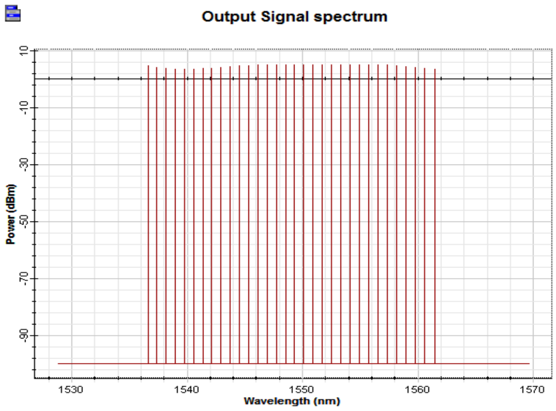


Fig 3 Received signal power spectrum

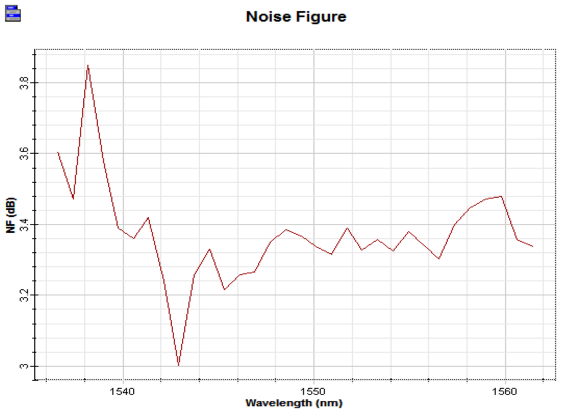


Fig 4 Noise figure of the proposed system

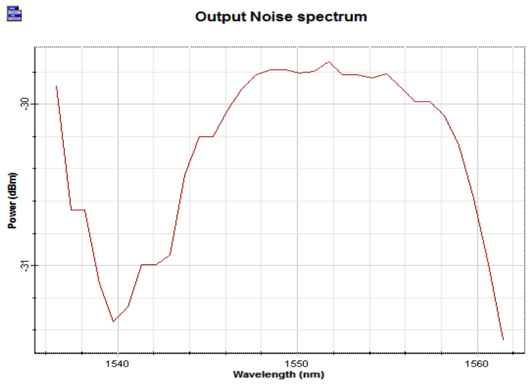


Fig 5 Noise power spectrum at receiver end

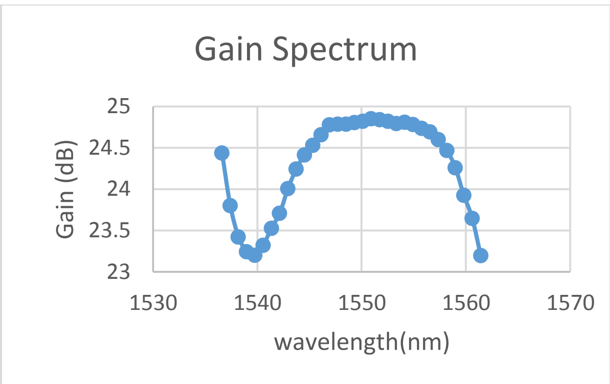


Fig 6 Gain Spectrum of the WDM system.

## 4. CONCLUSION

The successful deployment of WDM systems is directly related to the emergence of high-performance optical amplifiers. Flat-gain optical amplifiers across the whole communication bandwidth are needed to ensure proper amplification of every channel in WDM communication systems. To perform amplifier gain equalization, it would be always be better to optimize the parameters through systematic study and cautious selection of components to get the desired spectrum instead of inserting active/passive components because it will definitely account for a fall in gain, higher cost factor and increased noise figure. In this study, a bi-directional EDFA is designed in such a way that a flattened spectrum is received in C-band with a good gain performance. This will be used in WDM application since the gain tilt is only 1.65 dB. Feedback methods are used to control the pump power to compensate the wavelength dependent gain fluctuations. Bi-directional pumping enables to satisfy the other criteria's of lowest noise figure and highest output power. Here, the launching input power to the EDFA is -17 dBm and maximum output power received is 5.11 dBm. The maximum gain of proposed system is 24.85 dB with the highest noise figure being 3.85 dB. The minimum value of output optical SNR received is 34.34 dB with a maximum value of 35.14 dB envisages good quality reception.

## REFERENCES


1. M.A.othman, M.M Ismail, M.H. Misran, M.A.M.Said and H.A. Sulaiman, EDFA for C-Band Optical Communication system, IJET-IJENS Vol:12 No.04
2. K. Motoshima," Dynamic Compensation of Transient Gain Saturation in Erbium-Doped Fiber Amplifiers by Pump Feedback Control", Photonic Technology Letters, Vol.5, issue 12, December 1993.
3. Finisar white paper, Introduction to EDFA Technology June 2009
4. A. M. Vengsarkar et al.," Long-period fiber gratings as band-rejection filters", " J. Lightwave Tech. 14, 1 (1996).
5. Sun, Y et al."A gain-flattened ultra wide band EDFA for high capacity WDM optical communications systems", 24th European Conference on Optical Communication, 1998
6. Hashimoto, M et al, "A new method for low noise automatic gain control of EDFAs for WDM systems in metropolitan networks", 27th European Conference on Optical Communication - ECOC, 2001
7. Haruaki Akashi et al, "An output power stabilized erbium-doped fiber amplifier with automatic gain control", IEEE Journal of Selected Topics in Quantum Electronics ; 3(4):1019 – 1026; 09/1997.
8. Chun-Liu Zhao et al, "Performance of optical automatic gain control EDFA with dual-oscillating control lasers", Optics Communications 224 (2003) 281–287.
9. Prachi Shukla, Kanwar Preet Kaur, "Performance Analysis of EDFA for different Pumping Configurations at High Data Rate", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-5, June 2013
10. A.Cem Çokrak, Ahmet Altuncu, "Gain and Noise figure performance of Erbium Doped Fiber Amplifiers(EDFA)", Journal of Electrical and Electronics Engineering,4(2),(1111-1122),2004
11. Tomlinson, W. J.; Lin, C., "Optical wavelength-division multiplexer for the 1–1.4-micron spectral region", Electronics Letters, vol. 14, May 25, 1978, p. 345–347. adsabs.harvard.edu
12. Ishio, H. Minowa, J. Nosu, K., "Review and status of wavelength-division-multiplexing technology and its application", Journal of Lightwave Technology, Volume: 2, Issue: 4, Aug 1984, p. 448–463

13. Cheung, Nim K.; Nosu Kiyoshi; Winzer, Gerhard "Guest Editorial / Dense Wavelength Division Multiplexing Techniques for High Capacity and Multiple Access Communication Systems", IEEE Journal on Selected Areas in Communications, Vol. 8 No. 6, August 1990 .
14. Gurdeep Singh et al, "Analysis of Long-Haul 96 x 100 Gb/s Duo binary DWDM Link in the Presence of Non-Linear Dispersion Using Fiber Braggs Grating", International Journal of Advent Research in Computer and Electronics (IJARCE) Vol.2, No.1, January 2015
15. Arora, A.; Subramaniam, S. "Wavelength Conversion Placement in WDM Mesh Optical Networks". Photonic Network Communications, Volume 4, Number 2, May 2002.
16. First discussion: O. E. Delange, "Wideband optical communication systems, Part 11-Frequency division multiplexing". hoc. IEEE, vol. 58, p. 1683, October 1970.
17. R. Lebref et al., "Theoretical Study of the Gain Equalization of a Stabilized Gain EDFA for WDM Application," J. Lightwave Technol. 15, 766 (1997).
18. Hyo Sang Kim et al, "Actively Gain-Flattened Erbium-Doped Fiber Amplifier Over 35 nm by Using All-Fiber Acoustooptic Tunable Filters" IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 10, NO. 6, JUNE 1998
19. Y. Sun et al., "Transmission of 32-WDM 10 Gb/s Channels Over 640 km Using Broadband, Gain-Flattened Erbium-Doped Silica Fiber Amplifiers," IEEE Phot. Technol. Lett. 9, 1652 (1997).
20. R. Deepa, R. Vijaya "Influence of bidirectional pumping in high-power EDFA on single-channel, multichannel and pulsed signal amplification", Optical Fiber Technology 14 (2008) 20–26
21. M. Tachibana, R. I. Laming, P. R. Morkel, and D. N. Payne." Erbium-Doped Fiber Amplifier with FlattenedGain Spectrum". IEEE PHOTONICS TECHNOLOGY LETTERS. VOL. 3, NO. 2, FEBRUARY 1991. pp 118-120
22. John P. Dakin, Robert G. W. Brown." Handbook of Optoelectronics", CRC Press, 17-May-2006