International Journal of Electrical and Electronic Engineering & Telecommunications

ISSN 2319 – 2518 www.ijeetc.com
Vol. 2, No. 2, April 2013

Research Paper

PERFORMANCE ANALYSIS OF 32-CHANNEL WDM SYSTEM USING ERBIUM DOPED FIBER AMPLIFIER

Usman J Sindhi[1]*, Rohit B Patel[2], Kinjal A Mehta[1] and Vivekananda Mishra[3]

*Corresponding Author: **Usman J Sindhi,** ✉ usindhi@yahoo.com

The gain flatness of Erbium-Doped Fiber Amplifier (EDFA) is a key device for Wavelength Division Multiplexing (WDM) application in modern optical network systems. The purpose of this paper is to correct the gain non-uniformity for each channel in order to equalize the amplitude gain in a Wavelength Division Multiplexing (WDM) system. The system is simulated using Optisystem software to achieve gain flatness of EDFA through optimized fiber length and pump power. The gains are flattened within 27 dB from 1546 nm to 1568 nm band of wavelength with Noise Figure (NF) <14 dB and Bit Error Rate (BER) 10-21 for 32-channels simultaneous amplification in a single stage EDFA. A WDM system which includes an EDFA is modeled and obtained maximum uniformed gains.

Keywords: EDFA, Gain flatness, Fiber length, Pump power, WDM

INTRODUCTION

EDFA is an optical amplifier that uses a doped optical fiber as a gain medium to amplify an optical signal. The signal which is to be amplified and a pump laser are multiplexed into the doped fiber, and the signal is amplified through interaction with the doping ions. EDFA is the best known and most frequently used optical amplifier suited to low loss optical window of silica based fiber. A particular attraction of EDFAs is their large gain bandwidth, which is typically tens of nanometers and thus actually it is more than enough to amplify data channels with the highest data rates without introducing any effects of gain narrowing. A single EDFA may be used for simultaneously amplifying many data channels at different wavelengths within the gain region. Before such fiber amplifiers were available, there was no practical method for amplifying all channels between long fiber spans of a fiber-optic link. One had to split all

[1] Department of EC, L D College of Engg., Ahmedabad, India.
[2] Department of EC, U V Patel College of Engg., Ganpat University, India.
[3] Department of EC, S V N I T Surat, India.

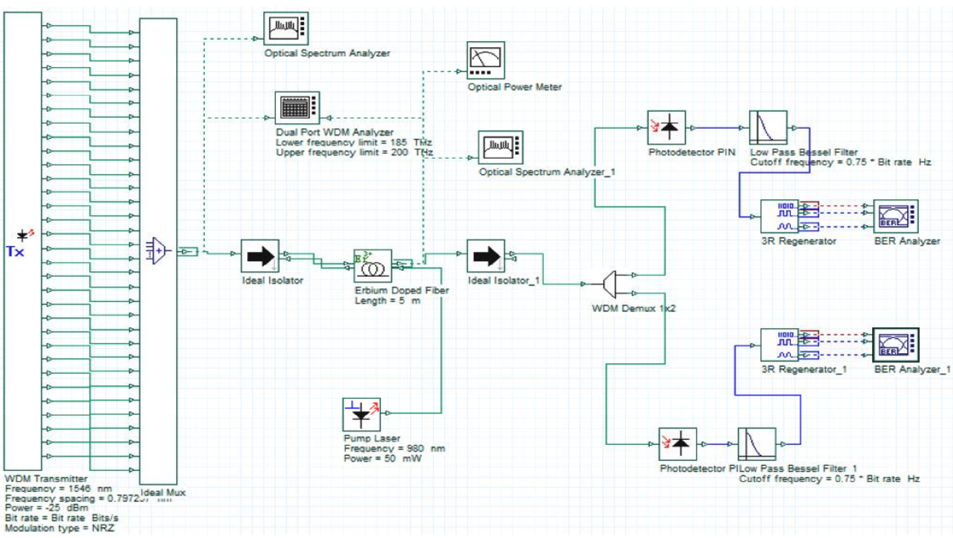
data channels, detect and amplify them electronically, optically resubmit and again combine them. The introduction of fiber amplifiers thus brought an enormous reduction in the complexity, along with a corresponding increase in reliability. In WDM systems by multiplexing, a stream of wavelength channels particularly in C and L-band regimes can simultaneously amplify to a desired power level where the amplification of any particular channel is dependent on the signal wavelength, the number of signals present in the system, the input signal powers and its absorption and emission cross-sections (Yoshida *et al.*, 1995). The gain-flattened Erbium-Doped Fiber Amplifier (EDFA) is a key component in long haul.

Multichannel light wave transmission systems such as the Wavelength Division Multiplexing (WDM) (Park *et al.*, 1996). One difficulty in implementing a WDM system including EDFA's is that the EDFA gain spectrum is wavelength dependent. In a WDM system, the EDFA does not necessary amplify the wavelength of the channels equally. EDFA in a WDM system are often required to have equalized gain spectra in order to achieve uniform output powers and similar Signal-Noise Ratios (SNR) (Sun *et al.*, 1999). There are several methods in designing a flat spectral gain EDFA such as by controlling the doped fiber length and the pump power (Park *et al.*, 1996; and Surinder and Kaler, 2006), proper choosing of optical notch filter's characteristic (Tachibana *et al.*, 1991), by using an acousto-optic tunable filter (Su *et al.*, 1993) and by employing an in homogeneously broadened gain medium (Goldstein *et al.*, 1995). This paper achieves gain flatness of EDFA by controlling the doped fiber length and the pump power for a given input power of –26 dBm and a desired output power of more than 8 dBm.

METHODS USED FOR PERFORMANCE ANALYSIS

The software Optisystem is used to design the EDFA in the WDM system. The system

Figure 1: Schematic Design of EDFA in WDM System



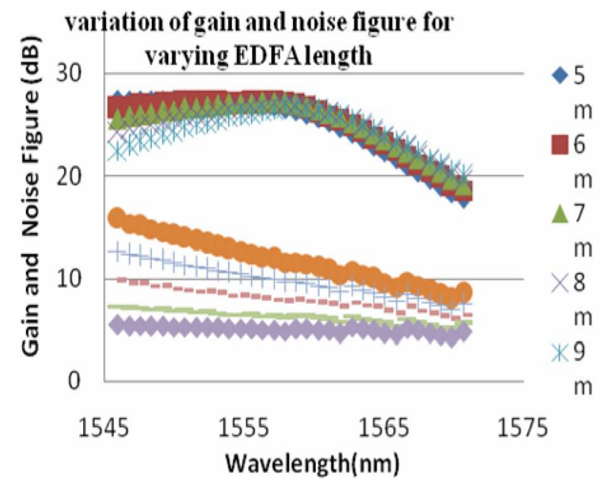
consists of 32 input signals (channels), an ideal multiplexer, two isolators, a pump laser, erbium doped fiber, demultiplexer, photo detector PIN, low pass Bessel filter and 3R regenerator as shown in Figure 1. The input of the system is 32 equalized wavelength multiplexed signals in the wavelength region of 25 nm (1546 nm-1570 nm) with 0.8 nm channels spacing. The power of each channel is –25 dBm. The pumping at 980nm is used to excite the doped atoms to a higher energy level.

An input optical isolator prevents Amplified Spontaneous Emission (ASE) and signals from propagating in backward direction. Otherwise, reflected ASE would reduce the population inversion, hence reducing the gain and increasing the noise figure. The output isolator prevents light from output reflections reentering in the EDFA. The desired gain is 23 dB and output power of more than 8 dBm with a gain flatness of less than 0.5 dB. The fiber length and pump power are selected as parameters to be optimized to achieve the desired gain under output power and gain flatness constraints.

RESULTS AND DISCUSSION

The pump power is 50 mW while the fiber length is bound between 5 and 9 m. The Gain and Noise Figure are measured by varying fiber length at a constant input power of –25 dBm as shown in Figure 2. The Gain and Noise Figure changes as the fiber length changes. For a given pump power, Gain and Noise Figure increases in initial stage and tends to decrease after the fiber length was optimized. It is observed that the optimum value of fiber length is between 4 m to 6 m due to the minimum losses.

Figure 2: Gain and NF Along the Fiber Length

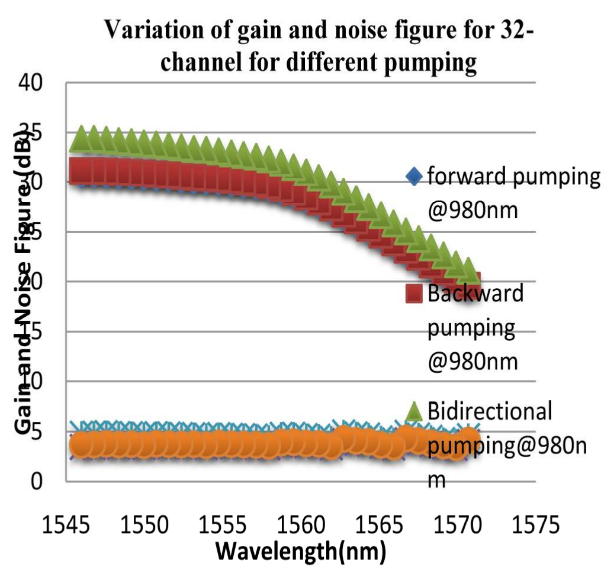


For different wavelength at a constant input power the optical gain and Noise Figure (NF) for multi channels amplification were measured for 50 mw pump powers. The fiber length was set at 5 m as the reference since the optimum fiber length is between 5 to 9 m. The gain flatness is a maximum difference among individual channels gains when the input power signals are equal. The variation of gain and noise figure for different EDFA length is shown for a 32-channel transmitter. Here we can observe that for smaller wavelength the gain is low and it increases with the higher wavelength and again falls down.

Figure 3 shows for a 32-channel transmitter the variation of gain and noise figure is shown. For forward and backward pumping gain is almost same and for bi-directional pumping the gain is high. Noise Figure for Counter pumping is high than the other pumping techniques. Noise figure for bidirectional pumping and co-pumping is same.

Figure 4 shows for the variation of gain and noise figure for different pumping wavelength is shown. Here backward pumping is used for

Figure 3: Gain and NF for Different Pump Techniques



32-channel WDM network. The input power per channel is –25 dBm. EDFA length is 5 m, pumping power is 100 m Watt. The wavelength range is 1546 nm to 1570 nm with 0.8 nm wavelength spacing. It was observed that gain for 1480 nm is higher than 980nm and noise figure at 1480 nm is less than 980 nm pumping wavelength.

Figure 4: Gain and Noise Figure at Different Pumping Wavelength

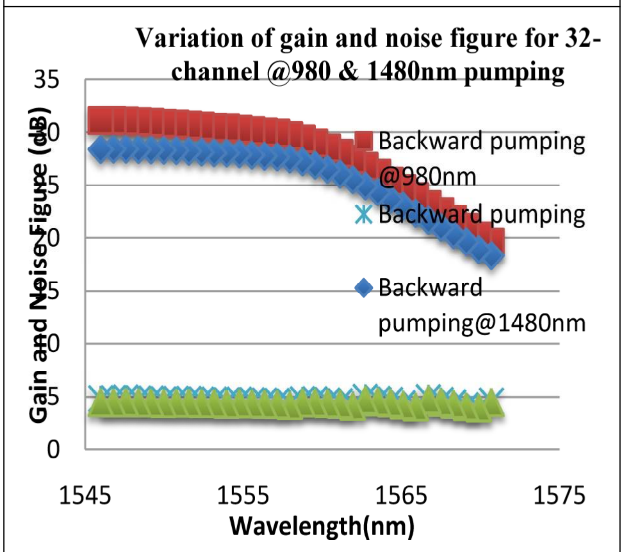


Figure 5 shows the results viewed from a visualize in the OptiSystem software. It displayed a clear view of the power for different wavelength1546 to 1570 nm. When the power (dBm) versus the wavelength (m). It is the 32-channel multiplexer output which power –25 dBm.

Figure 5: 32 x 1 Multiplexer Output Power

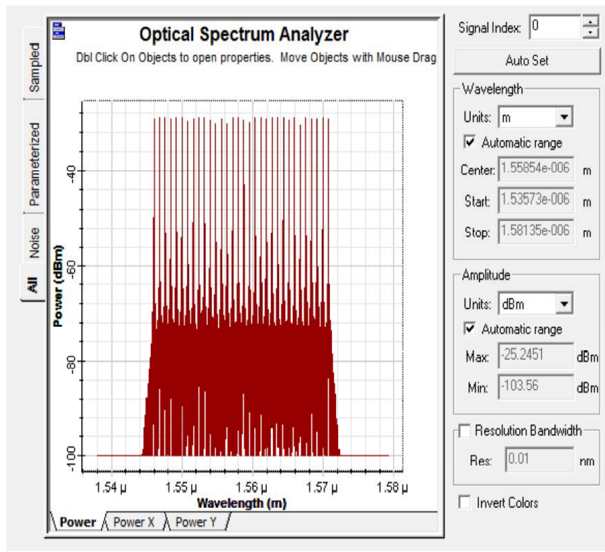
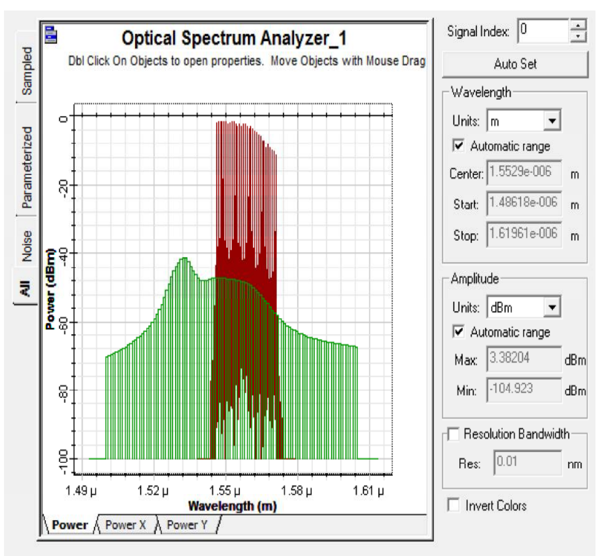


Figure 6 represents the EDFA amplify the 32-channel which is maximum value

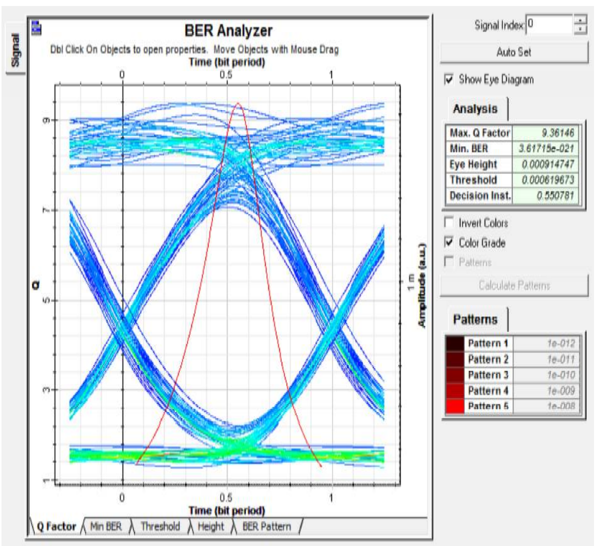
Figure 6: EDFA Output



–3.38 dBm. For each pump power, the output power increases and decreases after reaching a maximum value. As the fiber length increases, Er3+ ions available to excite increases and output power increases. After a certain length, when all pump power is exhausted, the unexcited Er3+ ions results in the decreased of output power.

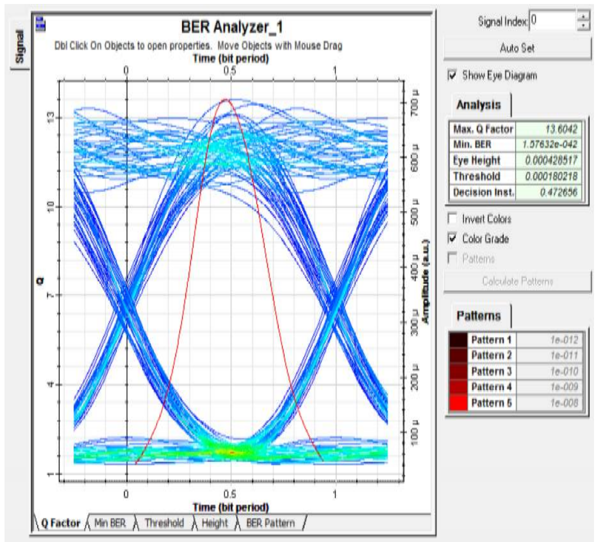
The performance of the system was analyzed using BER analyzer as shown in Figure 7. The eye pattern for channel 1 gives a big opening which means that the intersymbol interference (ISI) is low. The width of the opening indicates the time over which sampling for detection is performed. The optimum sampling time corresponding to the maximum eye opening, yielding the greatest protection against noise.

Figure 7: Eye Pattern (Channel 1)



The bit error rate (BER) was measured to be at an average of 3.617e-21 and Q-factor is 9.36 for channel 1. In Figure 8, the bit error rate (BER) was measured to be at an average of 1.567e-42 and Q-factor 13.0642 for channel 16.

Figure 8: Eye Pattern (Channel 16)



CONCLUSION

The population inversion can be controlled by proper choosing of fiber length and injected pump power to EDFA. The optimum fiber length is 5 m whereas the optimum pump power is 23 mW. The system for 32-channel amplification was designed with 27 dB intrinsically gain flatness from 1546 nm to 1570 nm bandwidth. The output power of 8.408 dBm and an average noise figure of 6 dB were obtained from the simulation. This WDM system has a good performance of BER which is in the range of 10^{-21} to 10^{-42} and Q-factor which in the range of 9 to 13.

REFERENCES

1. Bo-Ning H U, Wang Jing, Wang Wei and Rui-Mei Zhao (2010), "Analysis on Dispersion Compensation with DCF Based on Optisystem", 2nd International Conference on Industrial and Information Systems.

2. Bouzid B (2012), "Behavioral Variations of Gain and NF Owing to Configurations

and Pumping Powers", *Optics and Photonics Journal*.

3. Goldstein E L *et al.* (1995), "In Homogeneously Broadened Fiber Amplifier Cascade for Transparent Multiwavelength Light Wave Networks", *J. Light. Tech.*, Vol. 13, p. 782.
4. Ismail M M, Othman M A, Sulaiman H A, Misran M H and Meor M A Said (2012), "Performance Analysis of WDM and EDFA in C-Band for Optical Communication System", *IJRRAS*, Vol. 13, No. 1, Malaysia.
5. Kaler R and Kaler R S (2011), "Gain and Noise Figure Performance of Erbium Doped Fiber Amplifiers (EDFA) and Compact EDFAs", pp. 440-443, Elsevier.
6. Malekmohammadi A and Malek M A (2011), "Limitation in the Intrinsic Method of EDFA Gain Optimization for 32X10 Gbps WDM Systems", Elsevier.
7. Mir Muhammad Lodro and Muhammad Ali Joyo (2012), "32-Channel DWDM System Design and Simulation by Using EDFA with DCF and Raman Amplifiers", *International Conference on Information and Computer Networks IPCSIT*, Vol. 27, Singapore.
8. Park S Y *et al.* (1996), "Doped Fiber Length and Pump Power of Gain-Flattened EDFAs", *Elect. Lett.*, Vol. 32, p. 2161.
9. Su S F *et al.* (1993), "Flattening of Erbium-Doped Fiber Amplifier Gain Spectrum Sing an Acousto-Optic Tunable Filter", *Electro. Lett.*, Vol. 29, p. 477.
10. Sun Y, Srivastava A K, Zhou J and Sulhoff J W (1999), "Optical Fiber Amplifiers for WDM Optical Networks", *Bell Labs. Tech. J.*, Vol. 4, pp. 187-206.
11. Surinder Singh A and Kaler R S (2006), "Gain Flattening Approach to Physical EDFA for 16 × 40 Gb/s NRZDPSK WDM Optical Communication Systems", *Fiberand Integrated Optics*, Vol. 25, No. 5, pp. 363-374.
12. Tachibana M *et al.* (1991), "Erbium-Doped Fiber Amplifier with Flattened Gain Spectrum", *IEEE Photon. Tech. Lett.*, Vol. 3, p. 118.
13. Yoshida S, Kuwano S and Iwashita K (1995), *Electron. Lett.*