JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# CROSSTALK REDUCTION IN C+L BAND ERBIUM DOPED FIBER AMPLIFIER BY INCORPORATING OPTIMAL PARAMETERS

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## Abstract

To fulfill the needs of current bandwidth hungry internet services, optical amplifiers are required that can provide better Gain, less crosstalk and large bandwidth. In order analyze the effects of different physical parameters such as amplifier's fiber length, core radius, pump power and pump wavelength in a single stage C+L band erbium doped fiber amplifier, a system 32 channel system is proposed at low input power levels. Gain flatness of 4.59 dB is achieved without using any external components and multiple stages of EDFAs in C+L band. we proposed a single stage low cost C+L band EDFA amplifier incorporating fiber bragg gratings (FBG). It is observed that FBG incorporated system exhibits improved gain flatness (2.43 dB) as compared to without FBG system (4.59 dB). Crosstalk is major degrading effect in WDM incorporated EDFA systems. It is perceived that proposed EDFA-FBG offers low crosstalk. It is noteworthy that gain fatness of 2.43 dB is achieved without using any costly components such as isolators, GFFs and multiple stages of EDFAs.

**Keywords- C+L band, EDFA, Gain flattening filters, Gain, noise figure**

## Introduction

Ever since the beginning of time, mankind has found different ways to communicate with each other. People were assigned the duties of messengers to carry the message from one place to another. With the development of science and technology things were entirely changed. Advances in the field of optical communication started with the discovery of lasers in the 1960's. The first optical fiber link was installed in the late 1970's and was used for transmitting telephony signals at about 6 Mbps over distance of approximately 10 km [1]. Optical Communication has been used since 90's for high speed transmission of data. Optical communication is the kind of communication that reliant on the light transmission from one end to other terminating point, despite the movement of electrons (electric current). Transmissions reliant on optical fiber have given the paradigm shift in the communications as well as cater and prominent part in the initiation of the networking era [2] [3]. The Erbium-Doped Fiber Amplifier (EDFA) is a key component in long haul. So, the performance of EDFA based WDM system needs improvement [4]. Performance of DWDM system decreases as in the increase of no. of channels. This is because gain is variable for different wavelengths [5]. So design of EDFA which provide flat gain over different wavelength is great area of research. Analysis to increase the gain of EDFA has been reported from survey but either methods were complex or increase the cost of the system [6][7][8]. Crosstalk reduction is also a key factor in EDFA enhancement. Although to increase the gain of EDFA is reported earlier, with the increase of pump power gain tends to increase. But noise also increases with pump power [9]. Also co and counter pumping also analyzed before for gain flattening ,both the pumping techniques has their own drawbacks. In co-pumping low gain but good noise figure is obtained while in counter pumping high gain with high noise figure is obtained [10]. Reported works in C and L band amplifications are studied and it is found that the proposed methods such as multiple pumps, many stages of amplifier to amplify L band along with C band wavelength, isolators, gain flattening filters etc [11][12][13]. So, a cost effective technique with optimal parameters of amplifier is required to get better performance.

**System setup**

In this work, the main focus is to design a C+L band single stage erbium doped fiber amplifier with improved gain flatness and less crosstalk. First and foremost, different physical parameters of EDFA amplifier are investigated to analyze gain and gain flatness over different bands. In order to analyze the performance of EDFA, parameters considered such as EDFA length, core radius of EDF fiber, input power levels and different pump powers are tested. Figure 1 shows the block diagram of WDM system which is used in this work for physical parameter analysis and represents the EDFA gain optimization for WDM system optical network design consist of WDM Transmitter (32 input Signals channels), Ideal Multiplexer, Pump laser, Erbium Doped Fiber (EDF), WDM analyzer and optical spectrums. The WDM Transmitter holds 32 equalized wavelengths in C and L band that fed to Ideal Multiplexer. Power of each channel is varied from -30dBm to -14 dBm with the difference of 4 dBm to make system operational at low power. Advantage of low power system is that it has more life time than high power system because high power causes more thermal noise to laser. While pump power used is 980 nm-980 nm and 980 nm-1480 nm alternatively for analysis to excite the doped atoms to a higher energy level. The parameters which are selected to be optimized in achieving flattened gain is fiber length and core radius using bidirectional pumping. After optimizing, optical signal is passed through the erbium fiber of varied fiber length 10 m 30 m. The signal from erbium doped fiber is then passes through the circulator which is mainly used to helps the signal to pass in single direction. After circulator signals are accessed by WDM analyzer which is used to provide the information of gain and noise figure at each wavelength. In this work, comparison between the different core radius is performed by optimizing EDFA the help of simulation. Also length is also optimized along with the pump powers.

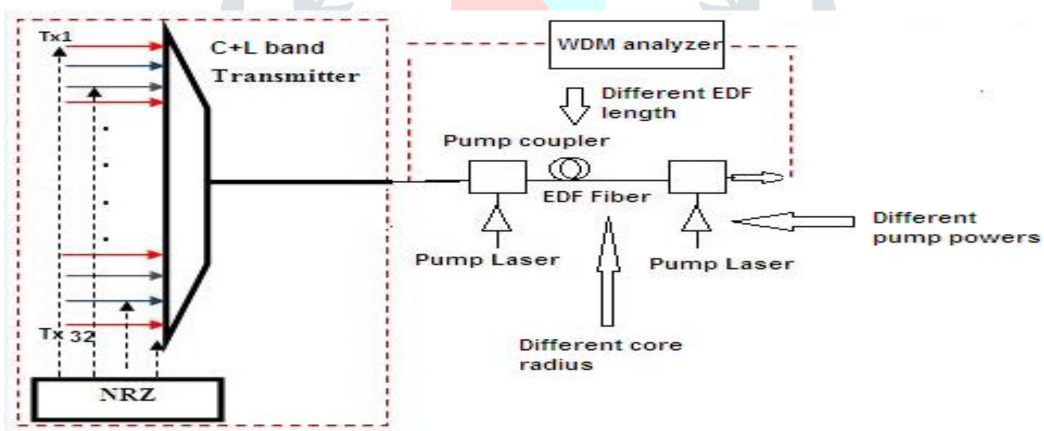



Figure 1 Proposed system setup for analysis at different physical parameters

**Results and discussions**

For the analysis of proposed system setup, first and foremost the laser launched power of the system is varied from -30 dBm to -14 dBm and analyze the gain at these values of EDFA in C+L band WDM system. Input power plays a vital role in amplifiers, as the gain also varied with the launched power levels. It also changes the gain flatness values in different band. Figure 2 depicts the graphical representation of gain with varied input powers. It is evident that with at the power level of -30 dBm, EDFA provides the maximum (34.18) gain and gain decreases with the increase in power levels. Also gain flattening values are reported for different power levels and it is also observed that as results revealed that improved gain flatness (4.59) is found at -26 dBm input power. Below and beyond this value of input power, gain flatness improvement reduces. So, input power -26 dBm in this proposed setup is optimal and fixed for further analysis. Gain flatness is observed as 6.49 dB, 4.59 dB, 5.24 dB, 6.78 dB and 9.67 dB on the power levels of -30 dBm, -26 dBm, -22 dBm, -18 dBm and -14 dBm respectively.

Also Figure 3 (a) represents the optical spectrum analyzer output on the screen that shows the power and wavelength of carrier signals in one go after multiplexer. Figure 3 (b) represents the optical spectrum after EDFA at -26 dBm.

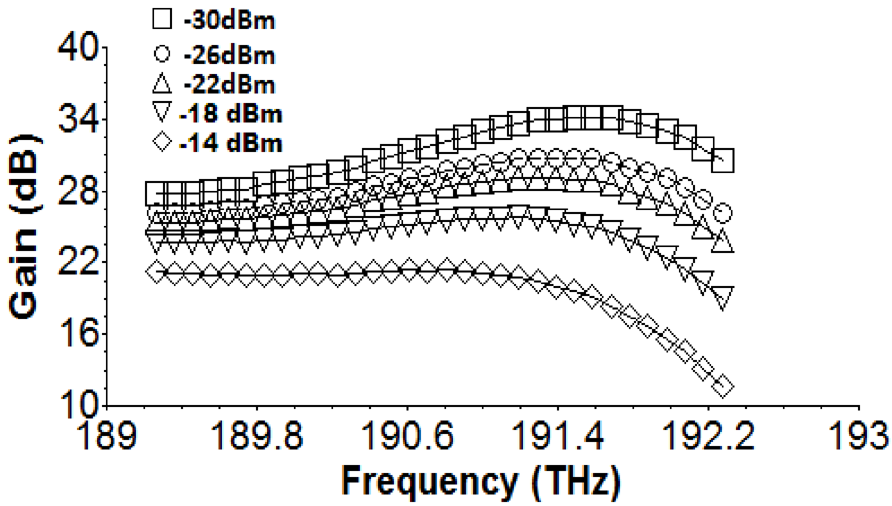
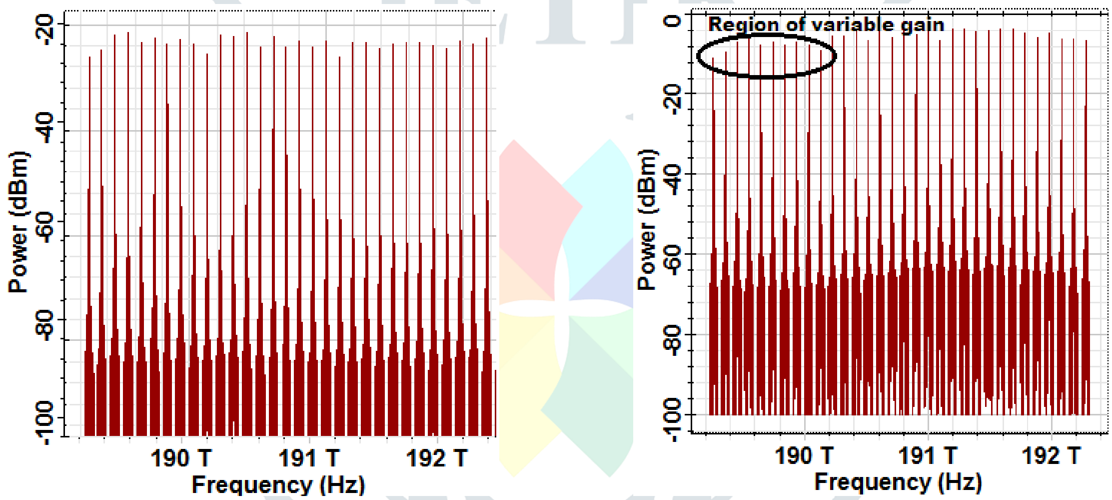



Figure 2 Gain of EDFA at different frequencies for input powers




(a) (b)

Figure 3 Optical spectrum analyzer output after (a) multiplexer (b) EDFA at -26 dBm

Further, a comparison has been done for different core radius of erbium doped fiber to evaluate gain and its flatness over two bands wavelength WDM system. Core radius is varied from 1.8 µm to 2.3µm with the gap of .1 micro meters. It is also interesting to investigate the different radius to see the effects over gin and flatness of amplifier. From the results, it is observed that proposed system provides maximum gain flatness for 2.2 µm core radius as shown in Table 1.

Table 1 Gain flatness values at different core radius

| Core radius (µm) | Gain flatness (dB) |
|---|---|
| 1.8 | 4.76 |
| 1.9 | 4.60 |
| 2 | 4.67 |
| 2.1 | 4.68 |
| 2.2 | 4.59 |
| 2.3 | 4.69 |

The pump power is set to 80 mW and 48 mW for co and counter pumps respectively and the length of the fiber is bound between 15 and 35 m. Therefore the output power and gain are measured by varying the EDFA length at a constant input power which is -26 dBm.

Table 2 Gain flatness values at different lengths of EDF

| EDF Length (m) | Gain flatness (dB) |
|---|---|
| 15 | 14.19 |
| 20 | 10.54 |
| 25 | 7.34 |
| 30 | 4.59 |
| 35 | 7.99 |

Optical fiber length has a great impact on the gain of amplifier and thus studied in this work. Figure 4 depicts the performance of the EFDA at different link lengths. It is evident that there is great fluctuation in gain of two bands. For the values of flatness of gain at different lengths of fiber is shown in Table 2.

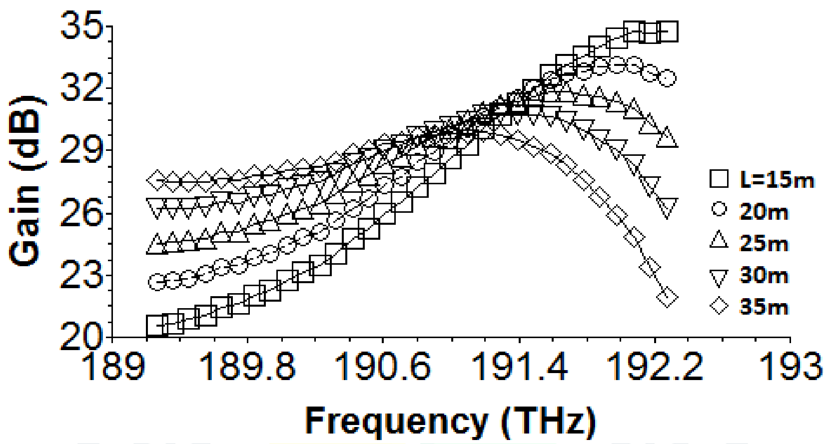



Figure 4 Gain versus frequency for different EDF length

From results it is clear the 30 m EDF fiber length is best to use for improved gain flatness in proposed system. Moreover, different pump wavelengths in co-pump and counter-pump are also tested to get improved gin and flatness. Pump wavelengths are 980 nm and 980 nm in co and counter pump and also 980 nm- 1480nm in co and counter pump respectively. It is observed from the Figure 5 that former case is better and provide improved gin flatness. In case of wavelengths are 980 nm and 980 nm, the obtained gain flatness is 4.59 dB and in 980 nm-1480nm the obtained flatness is 5.64. However, maximum gain reported for former case is 30.77 dB and later is 32.70 dB. So, again after the analysis, it is suggested that in C+L band WDM system with EDFA amplification, co and counter pump with wavelength 980 nm should be used.

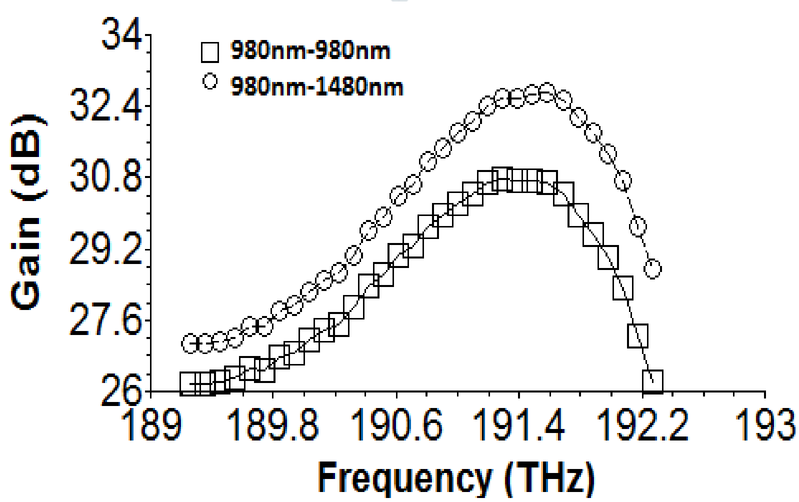



Figure 5 Performance of different pump wavelengths in proposed system

Finally, we have proposed a different setup with above mentioned optimal parameters in C+L band WDM system by using a low cost FBG (fiber bragg grating) to provide much improvement in gain flatness as shown in Figure 6. Also comparison of with and without FBG is evaluated in the work. Criteria for the evaluation are similar that we measure the output gain and flatness. Later on we will analyze crosstalk in the system by using with FBG system and without FBG system.

Figure 6 represents the block diagram of C+L band single stage EDFA amplifier for WDM systems. System architecture is simple that a 32 C+L band WDM signal are multiplexed by mux. Now, from the above investigation it is studied that singe EDFA amplifier do not amplify the L band wavelengths same as C band. Thus the flatness of gain varied and in order to improve gain flatness, we propose a new method. The frequencies that are amplifier EDFA to greater extent are reflected by FBG after multiplexer. FBG has three ports, one is input, second is transmitted port and last is reflected port. We set the frequency of the wavelengths that needs to be transmitted and also set the bandwidth of reflected wavelengths. Reflected wavelengths are attenuated through attenuator and again combined with transmitted wavelengths. Combined signal is now fed to EDFA and results are analyzed.

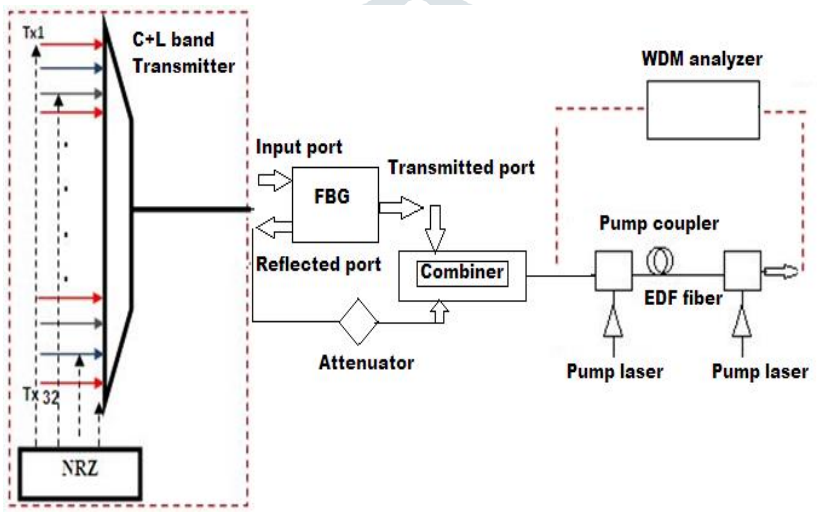



**Figure 4.6** System setup incorporating FBG

Figure 7 represents the comparison of with and without FBG proposed setups in terms of Gain. It is reported that gain flatness of 2.43 dB is achieved with FBG low cost system that has single stage without the employment of isolators, gain flattening filters and other costly methods.

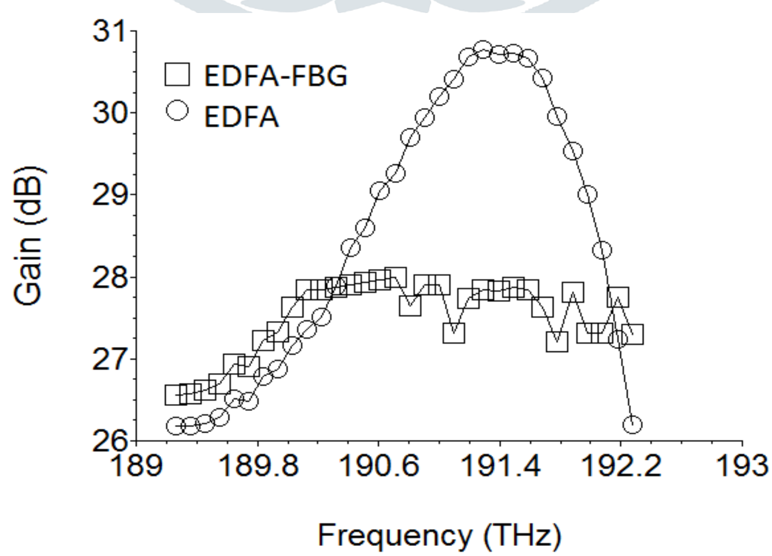



Figure 7 Gain of with and without FBG in EDFA system

Further crosstalk is investigated for with and without FBG systems in EDFA. It is represented in Figure 8. It is observed that crosstalk in case of FBG-EDFA is less as compared to other system in C+L band WDM system. Crosstalk is calculated from the formula as expressed:

$$\text{Crosstalk} = \frac{p_{1,\text{out}}(p_{2,\text{in}} = \text{off}) - p_{1,\text{out}}(p_{2,\text{in}} = \text{on})}{p_{1,\text{out}}(p_{2,\text{in}} = \text{off})}$$

where $P2_{in}$ is the input power, $P1_{out}$ is the amplified output power, and index 1 and 2 are two signal wavelengths. Of course, $P_1$ and $P_2$ are modulated signals.

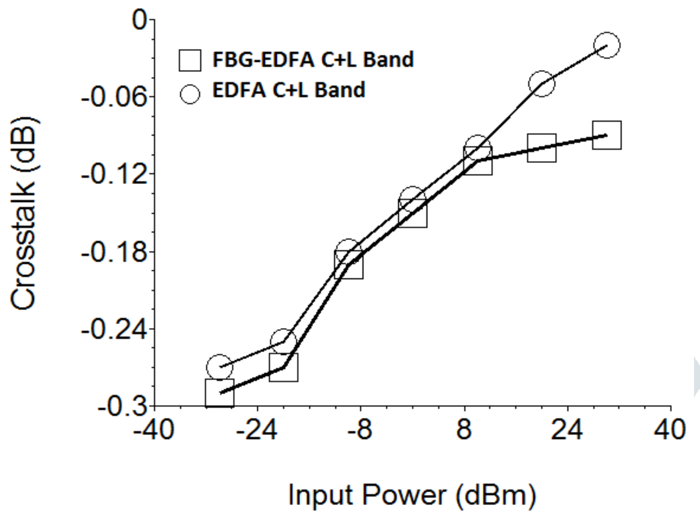



Figure 8 Crosstalk versus input power for with and without FBG in EDFA system

**Conclusion**

In this work, different physical parameters are investigated in C+L band WDM based system incorporating EDFA amplifier. Different physical parameters such as input power, EDFA core radius, EDFA fiber length and different pump powers in bidirectional pumps are investigated. System is analyzed at 10 Gbps and over 32 WDM channels and results revealed the optimal parameters after investigation. Optimal parameters that are best to provide high gain and gain flattens are found out to be -26 dBm input power, 2.2 micro meter core radius, 30 meter EDF length and 980 nm- 980 nm bidirectional pumping. At these factors, gain flatness of 4.59 dB is achieved without using any external components and multiple stages of EDFAs. Further a new setup is investigated and compared using low cost FBG in the system with reported technique in terms of gain and gain flatness. It is observed that FBG incorporated system exhibits improved gain flatness (2.43 dB) as compared to without FBG system (4.59 dB). Crosstalk as major degrading effect and evaluated in the system. It is also clear from the results that EDFA-FBG offers low crosstalk. It is noteworthy that gain fatness of 2.43 dB is achieved without using any costly components such as isolators, GFFs and multiple stages of EDFAs.

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