

Comparative Analysis of Bidirectional and Counter Pumping Techniques for EDFA based 32 channels WDM System using DCF

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Abstract: Optical fibers are employed in WDM networks to transmit information in the form of light pulse between the transmitter and the receiver. So, in this paper, the analysis of WDM network is done on the basis of EDF amplification and dispersion compensation mechanism by comparing two pumping techniques i.e. counter pumping and bidirectional pumping for 32 channels system. The system is analyzed on the basis of received power, Q-factor, BER (Bit Error Rate), Gain and Noise figure at different pumping powers in wavelength range of 1530nm to 1555nm at input power of -26dBm with 0.8 spacing between channels. The aim of this paper is to achieve maximum gain flatness and less noise or distortion.

Keywords: WDM; EDFA; Pump power; fiber length; DCF; BER.

I. Introduction

Communication is the transmission of information from one place to another through any medium. Mankind has been using many mediums for information transmission [1]. One of these mediums that really had a big impact on the transmission was coaxial-cable system. The first coaxial-cable system, deployed in 1940 [2], was a 3MHz system which could transmit 300 voice channels. But coaxial-cables mostly suffer from high cable losses and repeater spacing is also very limited. It proves costly for a longer transmission length. Further, in 1970s, optical fiber was first developed, which enhanced the telecommunication system and played a vital role in the era of communication world. Optical fibers are employed in WDM networks to transmit information in the form of light pulse between the transmitter and the receiver [3]. WDM systems have the potential to transmit multiple signals simultaneously [4]. But the light signals degrade in intensity when they travel along distance inside the fiber. So, it is required to amplify all the light signals simultaneously after a certain interval of light propagation to regain the original signal. Optical amplifiers are generally used to amplify the light pulses [5]. There are many optical amplifiers in use. The use of Erbium Doped Fiber Amplifiers is found in common [6]. EDFA is a silica fiber with active Erbium ions (Er^{3+}) as the gain medium. Er^{3+} has an optical fluorescent property so it is best suited for optical amplification. There are practically two wavelength windows C-Band and L-Band for amplifiers [7]. EDFA can amplify a wide wavelength range (1500nm-1600nm) simultaneously, hence is very useful in wavelength division multiplexing (WDM) for amplification [8-9]. In EDFA, when an optical signal such as 1550nm wavelength signal enters the fiber from input the signal is combined with a 980nm or 1480nm signal of pump laser through a pump coupler or WDM [10] as shown in figure1.

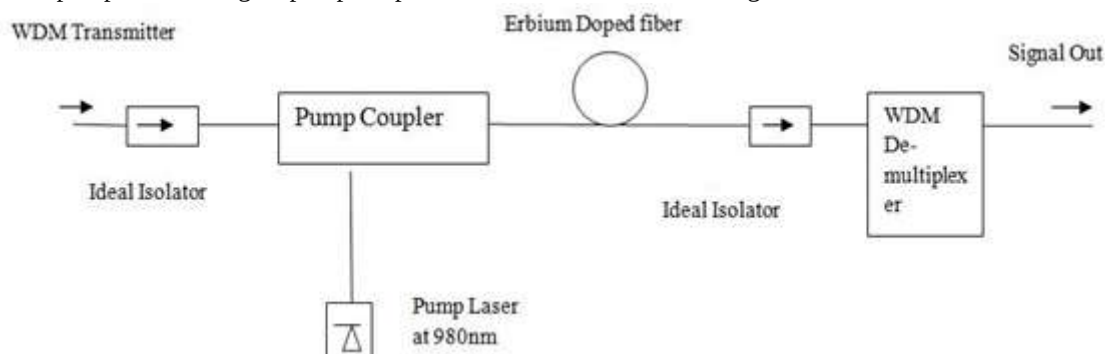


Figure 1: Block diagram of an EDFA [10]

Pumping of EDFA is done in different configurations i.e. co-pumping, counter and bidirectional [11]. In this paper, comparison between counter and bidirectional pumping is done and WDM system is analyzed on the basis of EDF amplification and dispersion compensation mechanism. In WDM networks, optical fibers are used and they suffer from heavy loss due to attenuation and dispersion [12]. Therefore it is essential to compensate the dispersion of the signal before its detection for error free transmission [13]. To compensate such dispersion losses there should be some device installed in the WDM network. One of the common methods used is:

deploying Dispersion Compensating Fibers (DCF) within a network to compensate dispersion [14]. DCF has negative dispersion and negative slope; its value is approximately five to ten times that for single mode fiber. The dispersion value for DCF component is chosen in such a way that it will compensate the loss occurred due to optical fiber transmission span [12]. The performance of EDFA based WDM depends on length of EDFA and pump power. The system is analyzed in terms of received power, Q-Factor, BER, Gain, Noise Figure [15]. Gain (G) is the ratio of the power of signal at output to the power of signal given at the input end as [16]:

$$G = P_s(L) / P_s(0) \quad (1)$$

where $P_s(L)$ is the signal power at length L ; and $P_s(0)$ is the signal power at the input of the EDFA.

Noise Figure is SNR (Signal to Noise Ratio) reduction ratio of input and output of the amplifier as:

$$NF = (SNR)_{in} / (SNR)_{out} \quad (2)$$

where $(SNR)_{in}$ is signal to noise ratio at input; and $(SNR)_{out}$ is signal to noise ratio at output of amplifier.

II. SYSTEM DESIGN AND ANALYSIS

(A) System Consideration

WDM system includes basically three components i.e. transmitter, communication channel, and the receiver. The transmitter section includes: 32 channels WDM transmitter, ideal multiplexer; communication channel includes ideal isolator, Erbium doped fiber, optical fiber, Dispersion Compensated Fiber; whereas photodiode and low pass filter are at the receiver end [17]. Eye diagram analyzer and optical power meter is used to visualize the simulation results.

(B) WDM System Design

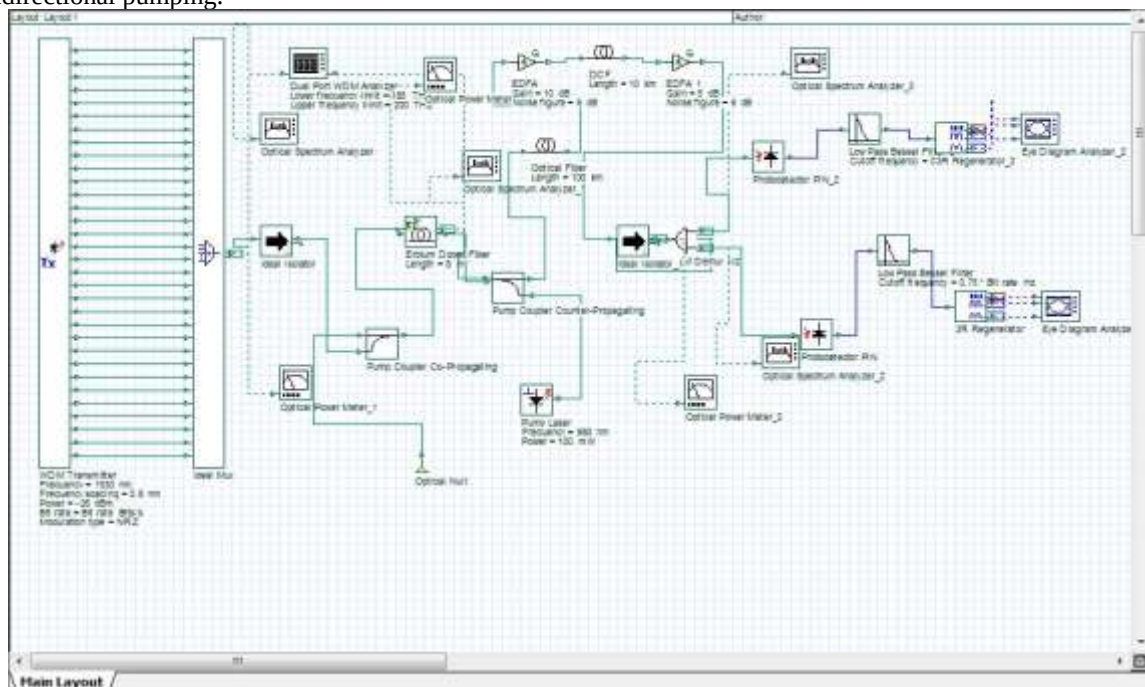
The WDM system is designed in OptiSystem v11.0. In this, 32 WDM signals are given at the input in the range of 1530nm-1555nm having frequency spacing of 0.8nm at 10Gbps data rate. The input power of -26dBm is fed to the channels. Length of EDFA is to be 8m [8]. Doped ions are excited to the higher energy level, when they are pumped at 980nm [9]. Length of the optical fiber and DCF is varied. To avoid the effects of Amplified Spontaneous Emission (ASE) produced in WDM system during amplification, isolator is used at the input end. It also prevents the propagation of the signal in backward direction. Otherwise, population inversion is reduced due to reflected ASE [18]. In this paper, the performance of the two pumping techniques is compared i.e. counter pumping and bidirectional pumping.

B1. Counter-Pumping (Backward Pumping) [19]:

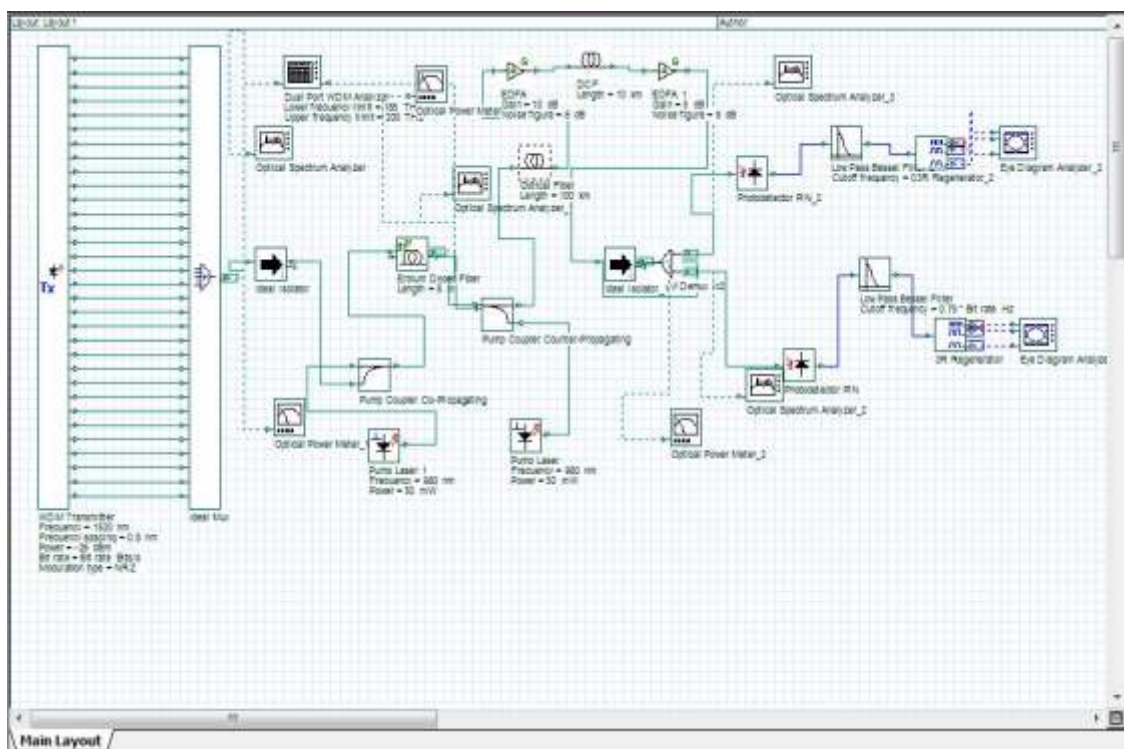
In Counter Pumping or backward pumping, both the signals i.e. input and pump travel in opposite direction to each other in the fiber. The direction of input and pump signal is not essential for amplification. They can travel in any direction.

B2. Bidirectional-Pumping [20]

In Bi-directional, both the signals that are input in one direction and pump propagate in both directions. One pump signal propagates in the same direction as the input signal and the other pump signal propagate in the opposite direction. Figure 1 show the WDM system designed in OptiSystem using counter pumping and bidirectional pumping.



(a)



(b)

Figure 2: Block Diagram of two pumping techniques (a) Counter Pumping (b) Bidirectional Pumping
Pumping is done by using pump coupler at both the ends. In case of counter pumping, null is given to pump coupler co-propagating and power to the pump coupler counter propagating where as in case of bidirectional pumping, power is given from both pump coupler co- propagating and pump coupler counter propagating.

III. Results and Discussion

On the basis of the literature, the optimized values of certain parameters are considered. The parameters which are to be considered are pump power and length of EDFA. The input power is taken to be -26dBm. Length of EDFA is 8m [8]. WDM system is analyzed by varying pump power so that minimum power is given to the circuit for which the analysis is done. Transmitted and received power is recorded by varying pump power from 20mW to 100mW at optical fiber length of 100km and DCF length of 10km. Also the values of Q-factor by varying power are recorded for both counter and bidirectional pumping. It is given in table 1.

Table 1: Performance of the system with the variation of pump power of EDFA at DCF length=10km, optical fiber length=100km

Pump Power to EDFA(mW)	Counter Pumping			Bidirectional Pumping		
	Output Power (in dBm)	Q-Factor		Output Power (in dBm)	Q-Factor	
		Output Channel1	Output Channel2		Output Channel1	Output Channel2
20	-1	0	0	-4.059	0	0
40	-1	0	0	1.706	4.342	4.245
60	-1	0	0	4.152	7.013	6.807
80	-1	0	0	5.716	9.182	8.973
100	7.124	8.799	8.287	6.870	10.967	10.631

From table 1, it is observed that at low values of pump power in counter pumping, received power is negligible up to 80mW and it is recorded as 7.124dBm at 100mW where as in case of bidirectional pumping, power is received even at low values i.e. at 40mW. So, at lower values of power, bidirectional pumping works and gives better performance. Therefore, it is again concluded from the analysis that for 32 channels EDFA based WDM system using DCF with bidirectional pumping outperforms that with counter pumping. Further, in case of bidirectional pumping, if the factor of pump power is analyzed, then it is observed that there is not much difference in the quality factor for 80mW and 100mW. It can be observed from table 1. So, to in order to make the proposed system cost effective, 80mW case is preferred to 100mW because with increase in power, system cost also increases. Gain and noise figure is also recorded to check the distortions in the system.

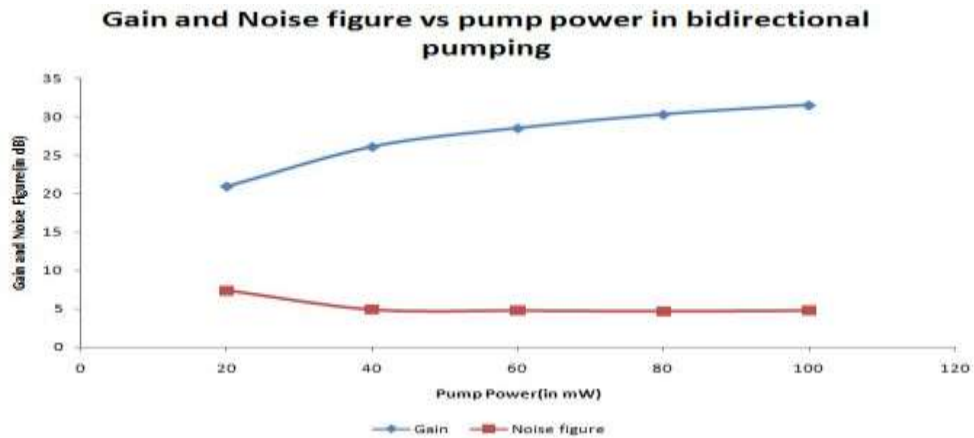


Figure 3: Gain and noise figure for bidirectional pumping with respect to pump power

The effect of pump power on gain and noise figure for bidirectional pumping is shown in figure 3. It can be observed that with increase in pump power system gain increases but noise on the system decreases for bidirectional pumping. Eye diagrams for both the pumping techniques at 80mW are shown from which Q-factor can be analyzed in figure 4.

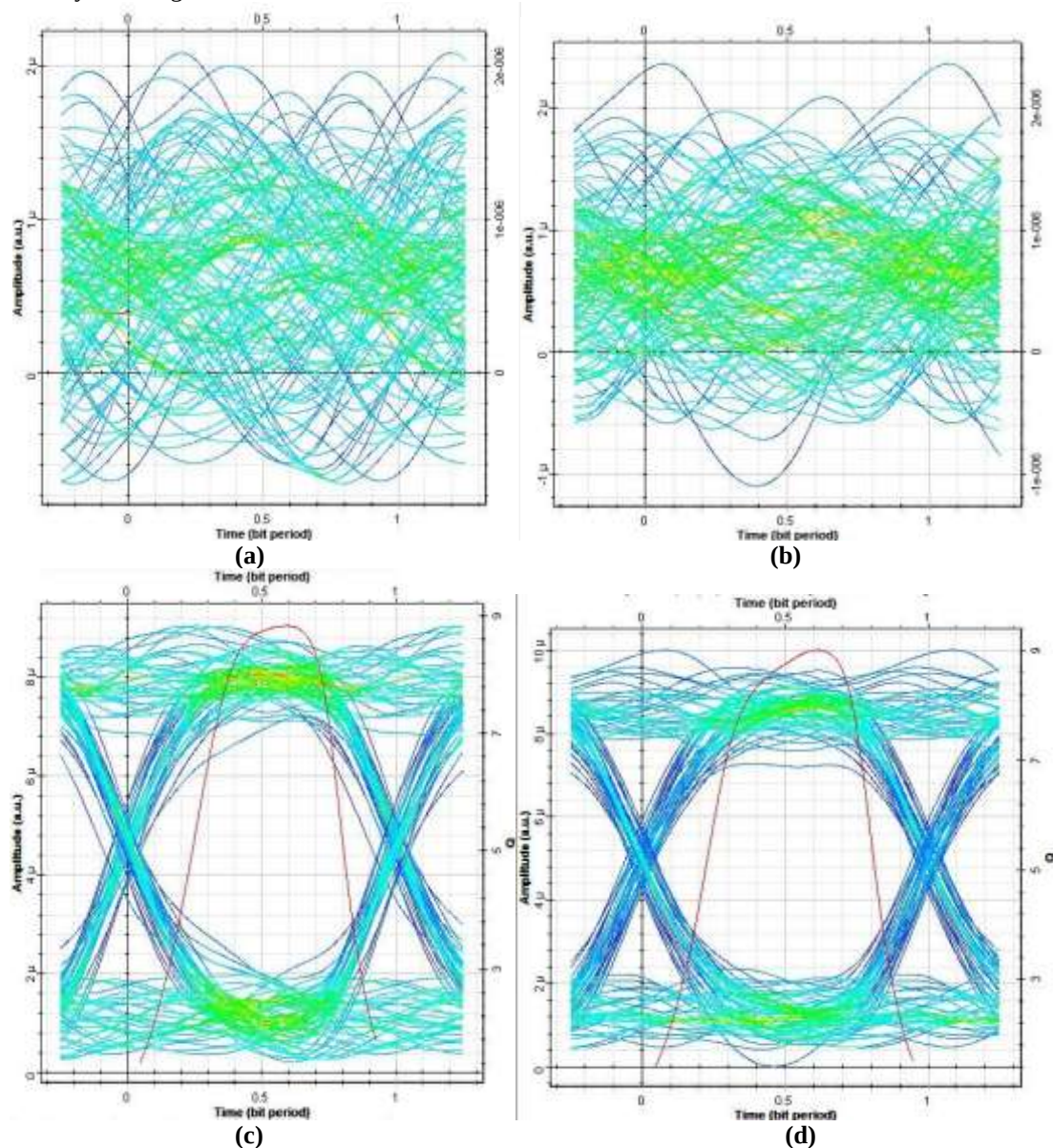


Figure 4: Eye diagram for 80mW (a) Counter pumping (channel1) (b) Counter pumping (channel2) (c) Bidirectional pumping (channel1) (d) Bidirectional pumping (channel2)

It can be clearly observed from figure 4 that in case of counter pumping, eye is almost closed or it can be concluded that no eye pattern is formed as the value of min. BER is observed as 1. While in bidirectional pumping; eye is quite open showing better performance in terms of Q factor for 80mW. Hence bidirectional is better than counter pumping and system is optimized at pump power of 80mW. Further, at 80mW pump power and with DCF length as 10km, the performance of the system is analyzed in terms of Q factor with varying length of optical fiber. Accordingly Q-factor is recorded as shown in table 2.

Table 2: Q-factor for varying optical fiber length with DCF= 10km, pump power=80mW

Length of Optical fiber (in km)	Q-factor	
	Output Channel1	Output Channel2
90	12.980	11.84
95	10.882	10.594
100	9.182	8.973
105	7.36	7.159
110	5.767	5.654

As shown in table 2 with increase in length of optical fiber, Q-factor decreases. Variation of Q-factor with respect to total system distance is shown graphically in figure 4.

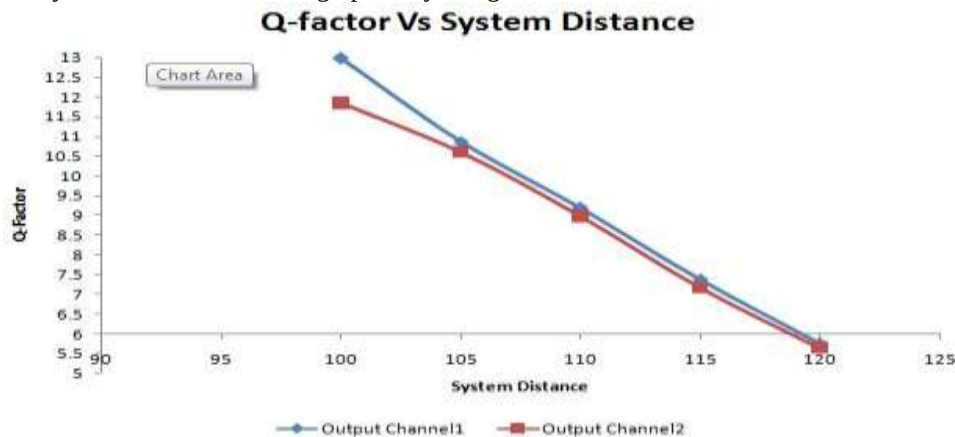


Figure 5: Variation of Q-factor for both output channels with varying distance for bidirectional pumping at 80mW pump power

It can be observed from table 2 and figure 5 that the acceptable transmission is obtained up to 105 km with respective values of Q-factor for channel 1 and channel 2 as 7.36 and 7.159. The total distance of system is attained to be 115km with fiber length of 105km and DCF length of 10km. The performance of the 32 channels of WDM system in terms of gain and noise figure in wavelength range of 1530nm to 1555nm is shown in figure 6.

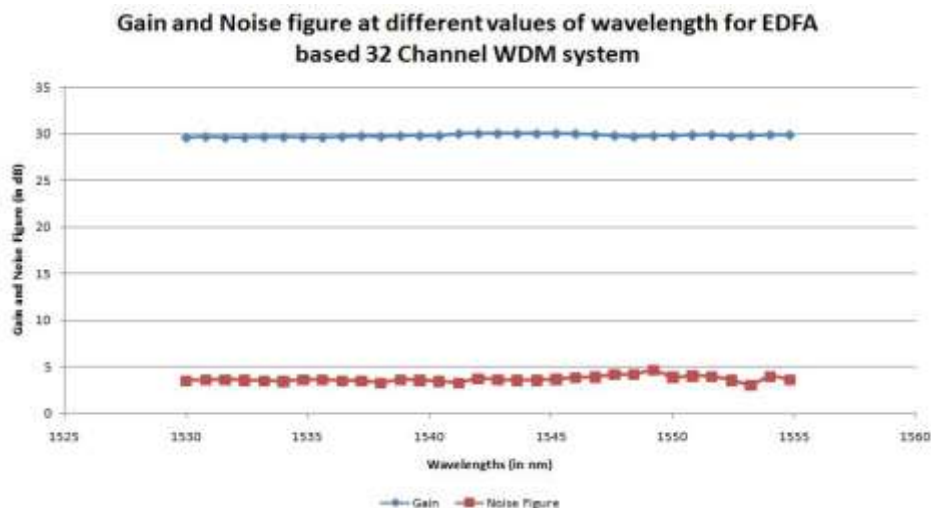


Figure 6: Gain and Noise Figure for EDFA based 32 Channel WDM System

From figure 5, it is clearly observed that almost a flat gain curve is obtained for the proposed system i.e. the variation in gain for all the wavelengths is less. More flat the gain is less distorted the signal is. Gain flatness achieved is to be 30 ± 0.5 dB and Noise figure is < 5 dB. Hence, it can be concluded that EDFA based WDM system for 32 channels with DCF using bidirectional pumping at 80mW pump power gives an acceptable transmission up to 105 km with flat gain curve.

IV. Conclusion

Comparison between two pumping techniques is given in this paper i.e. counter pumping and bidirectional pumping in terms of Q-factor for different values of pump power (20mW to 100mW) of EDFA. The system is operated in C-Band at input power of -26dBm and EDFA length of 8m at 980nm pump wavelength to attain maximum system distance using DCF of length 10km. For counter pumping received power is negligible up to 80mW where as in case of bidirectional pumping, power is received even at low values i.e. 20mW. If with the received power, Q- factor is considered then the acceptable performance is recorded for 80mW and 100mW. At both the values of pump power, bidirectional pumping provides better results. Further, in case of bidirectional pumping by keeping length of DCF to 10km and varying length of optical fiber, acceptable Q-factor is attained at system distance of 115km. Also, it can be concluded that the system with bidirectional pumping operating at 80mW power is optimized as the cost effective system up to system distance 115km.

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