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Comparative Analysis of EDFA based 32 channels WDM system for bidirectional and counter pumping techniques

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Abstract: With the increase in demand of capacity, Wavelength Division Multiplexing (WDM) is used in optical fiber network. In WDM, an equalized gain spectrum of EDFA is required so that the output power can be uniformed. So, in this paper the influence of bidirectional pumping is presented for 32 channels EDFA based WDM system. The performance of the system is analyzed on the basis of received power, Bit Error Rate, Q-factor at different pumping power in the wavelength range of 1530nm to 1555nm at power of -26dBm with 0.8 spacing. The performance of the WDM system with bidirectional pumping is compared to that with counter pumping.

Keywords: EDFA, Pump power, Fiber length, BER, WDM.

I. INTRODUCTION

History of the optical fiber communication is very long [1]. Initially the carrier waves were used, but for long span, there was no method that can be practically implemented for all the channels between fiber-optic links to be amplified. Evolutionary change came into existence with the introduction of amplifiers [2]. Amplifiers are of various types like Raman amplifier, Erbium Doped amplifier and Semiconductor amplifier [3]. EDFA is optical amplifier that is known best and recently used for optical window having low loss and contain the fiber having silica [4]. EDFA is preferred to use because its gain bandwidth is large, which is in the range of tens of nanometers. The channels of data can amplify without the gain narrowing effect at higher data rates [5]. For the amplification of an optical signal, doped fiber is used as a medium of gain. EDFA basic says when an optical signal at 1550 nm wavelength enters the EDFA; the signal is combined with a 980 nm or 1480nm pump laser through a wavelength division multiplexer [6]. Further, as the technology of optical communication increases, demand for increase in capacity of the system increases. As the number of channels increases, it becomes dense and also called Dense WDM [7].

For communication, there are practically two wavelength windows 1530nm to 1560nm (C-Band) and 1560nm to 1600nm (L-Band) [8]. EDFA can amplify a wide wavelength range (1500nm - 1600nm) simultaneously, hence is very useful in wavelength division multiplexing for amplification. Erbium doped ions can amplify the signal through the interaction at 1550nm [9]. EDFA is pumped in three ways: Co-Pumping, Counter pumping and Bidirectional Pumping [10]. It has been observed from the analysis that the results of co-pumping are not better than the bidirectional pumping. So, in this paper only two techniques are discussed: counter and bidirectional. The performance of EDFA based WDM System depends on the length of Erbium Doped Fibre and the pump power [5]. The performance of WDM system for long haul transmission is analysed in terms of Bit Error Rate, Noise Figure and power received [5].

II. SYSTEM DESIGN AND ANALYSIS

A. System Consideration:

Basically there are three sections of a WDM system i.e. transmitter, communication channel, and receiver channel. The transmitter section includes: 32 channel WDM transmitter, ideal multiplexer; communication channel includes ideal isolator, Erbium doped fiber, optical fiber where as photodiode and low pass filter are at the receiver end [11]. BER 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 given to channels. Doped ions are excited to the higher energy level, when they are pumped at 980nm [12]. Length of the optical fiber is 50km. 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 [13]. In this paper, the performance of the two pumping techniques is compared i.e. counter pumping and bidirectional pumping.

B.1 Counter-Pumping (Backward Pumping):

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

B.2 Bidirectional-Pumping:

In Bi-directional, both the signals i.e input and pump, propagate in one direction. But in the fiber, two pump signals travel. One pump signal propagates in the same direction as the input signal and the other pump signal propagates in the direction opposite to that of signal at the input. Figure 1 show the WDM system designed in OptiSystem using counter pumping and bidirectional pumping.

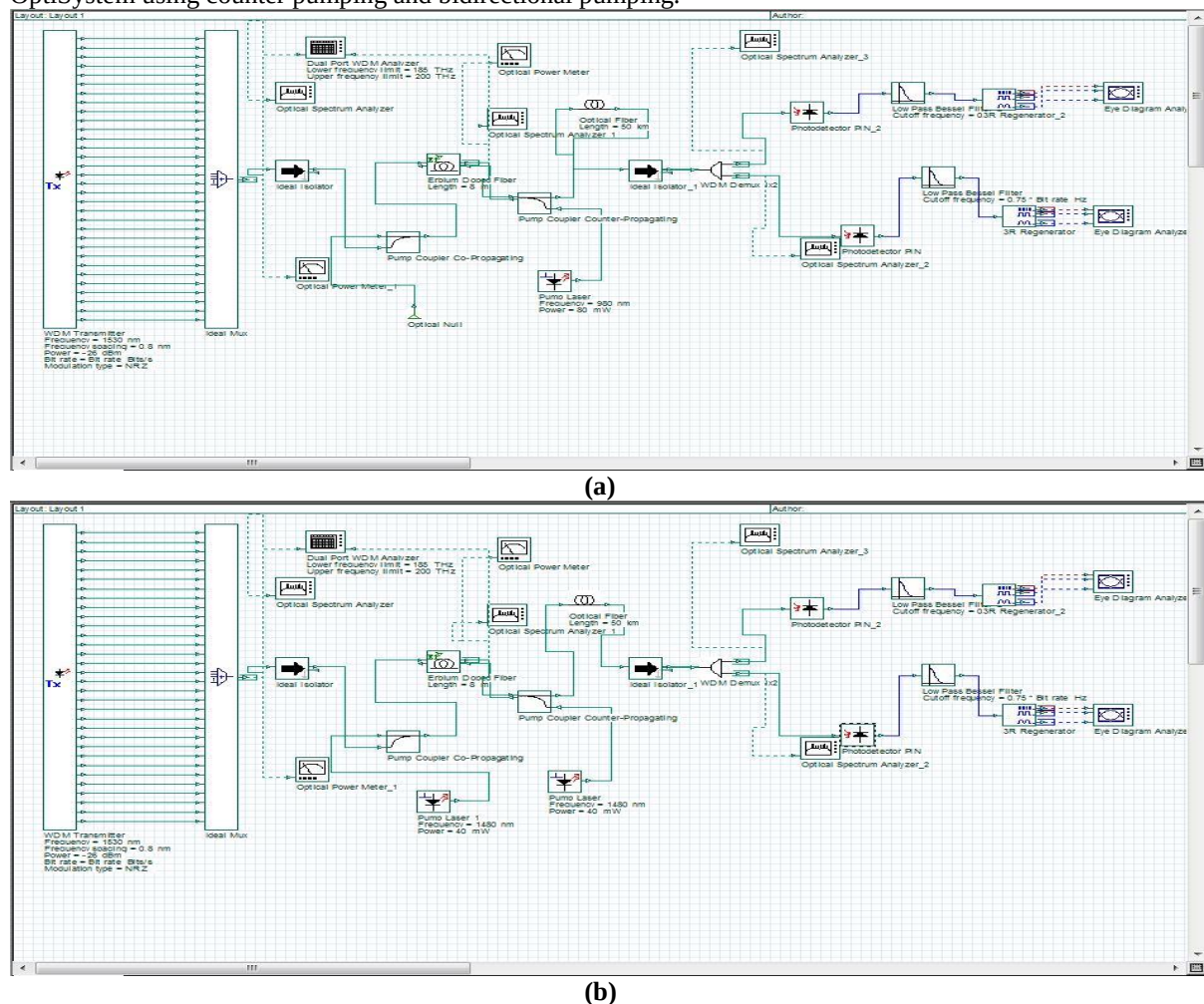


Figure 1: Block Diagram of two pumping techniques (a) Counter- Pumping (b) Bidirectional Pumping
Pumping is done by using pump coupler at both the ends. In case of counter pumping, null is given to pump coupler co-propagating and power to the pump coupler counter propagating where as in case of bidirectional 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 reviewed the optimized values of certain parameters are considered. The parameters which are to be considered are Pump Power, Length of EDFA and Length of optical fiber. The input power is taken to be -26dBm. Length of EDFA is 8m [5]. Length of optical fiber is considered to be 50km and power of pump is varied from 20mW to 100mW at 980nm wavelength. The pump power of the Erbium Doped Fiber is increased and corresponding received power is recorded for both the pumping techniques i.e. counter pumping and bidirectional pumping. It is shown in table1and table2 respectively.

Table1: Tx and Rx Power with the variation of Pump power of EDFA with counter pumping

Pump Power given to EDFA (mW)	Input power(E-6)	Input Power (In dBm)	Output Power(E-3)	Output Power (In dBm)
20	43.874	-13.578	1	-1
40	43.874	-13.578	1	-1
60	43.874	-13.578	1	-1
80	43.874	-13.578	1	-1
100	43.874	-13.578	51.313	17.102

Table 2: Tx and Rx Power with the variation of Pump power of EDFA with bidirectional pumping

Pump Power given to EDFA (mW)	Input power(E-6)	Input Power (In dBm)	Output Power(E-3)	Output Power (In dBm)
20	43.874	-13.578	3.670	5.646
40	43.874	-13.578	14.551	11.628
60	43.874	-13.578	25.574	14.108
80	43.874	-13.578	37.045	15.687
100	43.874	-13.578	48.382	16.847

From table and table 2, it can be observed that in case of counter pumping, received power is negligible up to 80mW and 17.1dBm at 100mW where as in case of bidirectional pumping, power is received even at low values i.e even at 20mW. Also, in bidirectional pumping at 20mW, total power of system is 20mW whereas the pump power at pump coupler co-propagating is 10mW and at pump coupler counter-propagating is 10mW. Hence, it can be concluded that the system works at low power only for bidirectional pumping. Counter pumping starts working from 100mW which is very high as compared to bidirectional pumping.

The performance analysis of counter pumping and bidirectional pumping in terms of BER and Q-factor is shown in table 3.

Table 3: BER and Q-factor for both pumping techniques for pump power of 20mW to 100mW

Pump Power given to EDFA(mW)	Counter Pumping				Bidirectional Pumping			
	Output Channel1		Output Channel2		Output Channel1		Output Channel2	
	BER	Q-Factor	BER	Q-Factor	BER	Q-Factor	BER	Q-factor
20	1	0	1	0	1	0	1	0
40	1	0	1	0	1.112e-5	4.237	8.712e-6	4.295
60	1	0	1	0	1.033e-11	6.700	2.906e-12	6.884
80	1	0	1	0	5.400e-19	8.825	1.026e-19	9.010
100	1.945e-17	8.415	2.146e-18	8.670	5.10e-26	10.483	2.957e-27	10.750

From Table 3, it can be observed that the minimum value of BER in counter pumping is 1 up to 80mW and e-18 for 100mW where as in bidirectional BER values varies from e-5 to e-27 as the pump power increases. In case of 80mW, counter pumping have minimum BER i.e.1 and for bidirectional it is e-19. At 100mW, counter pumping provides BER value of e-17 to e-18 and bidirectional pumping provides BER values in e-26 to e-27. So, from this it can be concluded that for 32 channels, the performance of bidirectional pumping is better than counter pumping. In case of bidirectional, although better results in terms of BER are found at 80mW and 100mW. Also, Q-factor for counter pumping is zero at low power levels where as in case of bidirectional pumping it increases with increase in pump power. The acceptable values of the Q-factor for optimized condition i.e at 80mW are 9.01 for bidirectional pumping.

Eye diagrams for both the cases 80mW and 100mW are shown from which Q-factor can be analyzed.

1. At pump power of 80mW for both counter and bidirectional pumping.

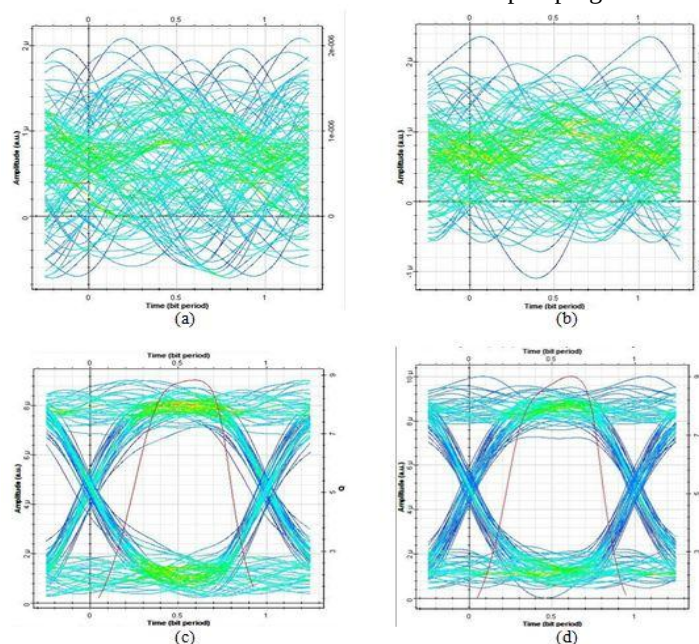


Figure 2: Eye diagram for 80mW (a) Counter pumping (channel1) (b) Counter pumping (channel2) (c) Bidirectional pumping (channel1) (d) Bidirectional pumping (channel2)

2. At pump power of 100mW for both counter and bidirectional pumping.

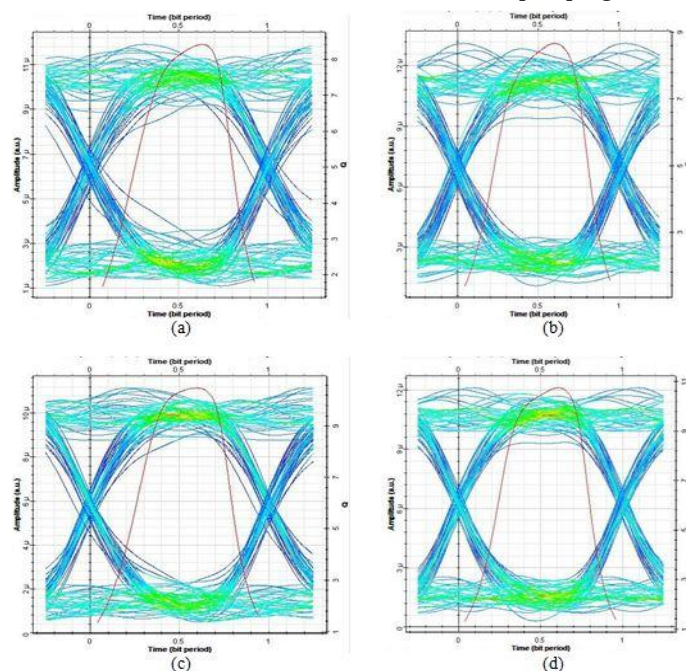


Figure 3: Eye diagram for 100mW (a) Counter pumping (channel1) (b) Counter pumping (channel2) (c) Bidirectional pumping (channel1) (d) Bidirectional pumping (channel2)

From figure 2, it can be clearly observed 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 1. Whereas in bidirectional pumping; eye is quite open showing better performance in terms of Q factor for 80mW. Figure 3 shows the eye patterns for both counter and bidirectional at 100mW power. Here also it can be observed that eye is quite open and wide for the bidirectional case and hence the Q-factor. Further from the above results, it can be observed that bidirectional pumping provides better results than counter pumping at each level of power. If the case of 80mW is considered then only bidirectional pumping works whereas in case of 100mW, both will give result but better results are obtained in case of bidirectional. Further, if the factor of cost is considered then the system with bidirectional can be optimized to operate at 80mW because with the increase in power system cost also increases. The optimized value of BER and Q-factor are received at 80mW pump power.

IV.CONCLUSION

Comparison of two pumping techniques are given in this paper i.e counter pumping and bidirectional pumping in terms of BER(Bit error rate) and Q-factor for different values of pump power(20mW to 100mW) of EDFA in C-Band at input power of -26dBm and EDFA length of 8m at 980nm pump wavelength. For counter pumping received power is negligible up to 80mW and 17.1dBm at 100mW whereas in case of bidirectional pumping, power is received even at low values i.e 20mW. If with the received power, BER factor is considered then the acceptable performance is recorded for 80mW and 100mW. At both the values of pump power, bidirectional pumping provide better results. Also it can be concluded that the system with bidirectional pumping operating at 80mW power is optimized as the cost effective system.

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