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Comparative Analysis of EDFA based 64 channel WDM systems for different pumping techniques

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Abstract – Wavelength Division Multiplexing using optical network is widely used in telecommunication system because it play an important role in next upcoming networks. So,the different pumping techniques for 64 channel WDM system for different length of Erbium doped fiber are discussed in this paper. For the same, system is analyzed on the basis of Bit Error Rate (BER), Received power and Q-Factor in the wavelength range of 1530nm to 1562nm at power-26dBm with 0.5nm spacing. The effect of different pumping techniques is also compared to find the suitable pumping technique and optimized BER at the receiver end.

Index Term – EDFA; Pump power; Fiber length; Bit error rate; WDM

1 INTRODUCTION

FOR the past two decades, Optical Fiber Communication has been advanced rapidly as it is the process of achieving transmission bandwidth using optical waves as carrier. As the time goes for the further improvement of Optical Fiber Communication, need of coherent optical sources arises and lasers are developed [1]. But when a signal travels in an optical fibrevarious losses like attenuation, tap splice etc. occurs. In presence of such losses, it is difficult to detect the received signal. Therefore, for the long transmission, these losses have to be overcome in fibre using different means. One such mean is the use of fibre amplifier. Also, far before, the optical signals were converted to electrical signal then amplified and then reconverted to optical signal. But it was a complex and costly process. As the optical amplifiers are introduced, the conversion of signal to electrical signal is not required. So, optical amplifiers revolutionized the optical fibre communication field [3]. Optical amplifiers broadly are of two types: semiconductor amplifier and fibre amplifier. Fibre amplifiers are divided into Erbium Doped Fibre Amplifier (EDFA), Raman amplifier and Brillouin amplifier [4].

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For communication, there are practically two wavelength widows 1530nm to 1560nm(C-Band) and 1560nm to 1600nm (L-Band) [5]. EDFA can amplify a wide wavelength Range (1500nm - 1600nm) simultaneously , hence is very useful in wavelength division multiplexing for amplification. It is a

Conventional Silica fibre heavily doped with active Erbium ions as the gain medium. Due to its property of fluorescence, Erbium ions are efficiently used for amplification in optical domain [6]. 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 device. The input signal and pump laser signal pass through fibre doped with Erbium ions .Erbium doped ions can be amplified the signal through the interaction at 1550nm [2]. EDFA is pumped in three ways: Co-Pumping, Counter pumping and Bidirectional Pumping. The performance of EDFA based WDM System depends on [7]:

1. Length of Erbium Doped Fibre
2. Pump Power

The performance analysis of a WDM (Wavelength Division Multiplexing) system employed for long haul transmission is carried out in terms of Bit Error Rate (BER), Noise Figure and received Power [8]. In this paper, different techniques of pumping i.e. co-pumping, counter-pumping and bidirectional pumping are analyzed for 64 channels in C- band [9] at 0.5 spacing for pump laser at 200mW at 980nm .

2 SYSTEM DESIGN AND ANALYSIS

2.1System Consideration:

There are three basic sections of a WDM system i.e. transmitter, channel and the receiver. The transmitter section includes: 64 channel WDM transmitter, ideal multiplexer; communication channel includesideal isolator, Erbium Doped Fiber, Optical Fiber ; whereas Photodiode, low pass filter are a part of the receiver section[6]. BER analyzer and optical power meter are used to analyze the simulation results.

2.2WDM System Design:

The system is designed in OptiSystem v7.0. In this, 64 channel WDM signals are given at the input in the range of 1530nm-1562nm having frequency spacing of 0.5nm at 10Gbps. The input power of -26dBm is given to the channels. Doped ions are excited to the higher energy level, when they pumped at 980nm.To prevent the effect of Amplified Spontaneous Emission(ASE), isolator is used at the input end which also prevent the propagation of the signal in backward direction. Otherwise, population inversion is reduced due to

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reflectedASE. Also,in EDFA, reflections of the output re-enter, and to overcomethis, isolatoris used at the output [7]. In this paper, three pumping techniques are compared i.e. Co-pumping, Counter pumping and Bidirectional pumping.

2.2.1 Co-Pumping (Forward Pumping):

In Co-Pumping, the signals i.e input and pump, travel in the same direction in the fiber. These signals are combined using a pump co-coupler or wavelength division multiplexer. Inside the fiber, pump energy is given to signal at the input and amplified signal is received at the amplifier's output. In this design, for the propagation of the signal in one direction, isolators are used.

2.2.2 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.

2.2.3 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 propagate in the same direction as the input signal and the other pump signal propagate in the direction opposite to that of signal at the input.

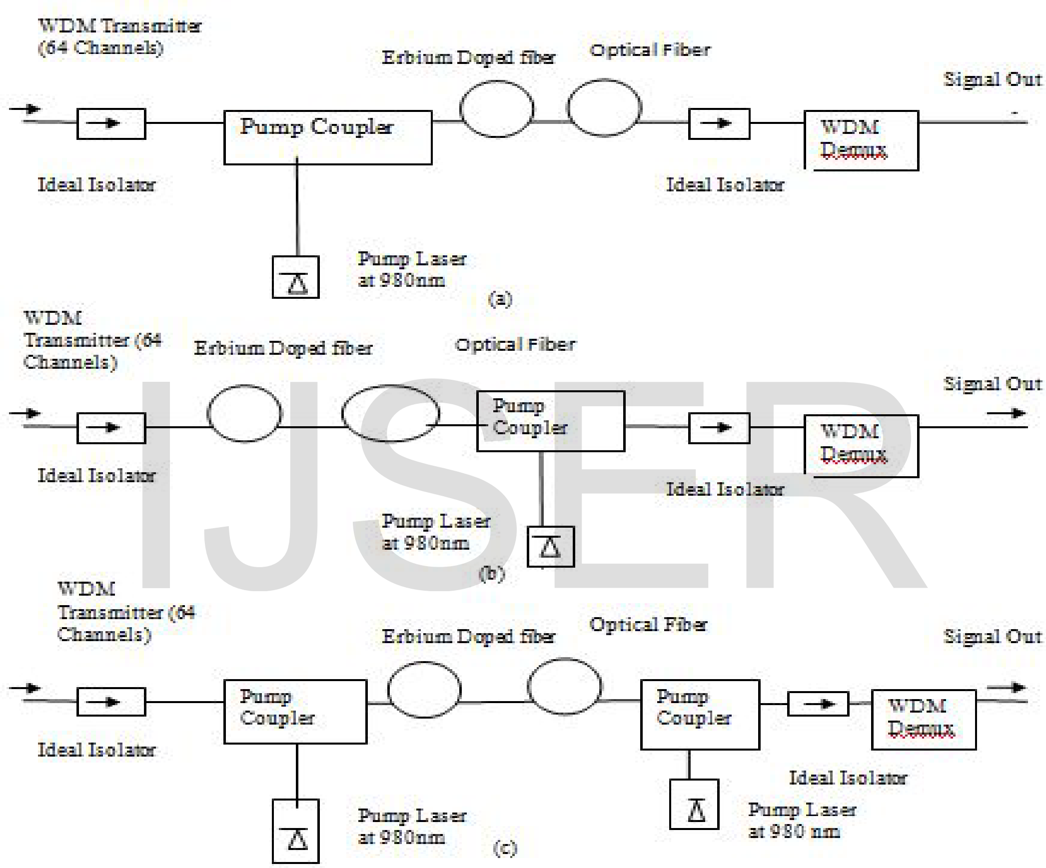

Figure1: Block Diagram of three pumping techniques (a) Co-Pumping (b) Counter- Pumping (c) Bidirectional Pumping

3 RESULTS AND DISCUSSION

Optimization of different parameters is needed to be done so that system performance does not degrade too low. The parameters which are to be considered are pump power, length of EDFA and length of optical fiber. Input Power is taken to be -26dBm. Length of EDFA is varied from 4m to 10m [4]. Length of optical fiber is taken to be 25km andoptimized power of the pump is200mW at 980nm wavelength. Length of the Erbium Doped Fiber is increased and corresponding received power is recorded for different pumping techniques as shown in table1, table2, table3, table4.

TABLE1

POWER WITH THE VARYING LENGTH OF EDFA FOR CO-PUMPING TECHNIQUE

Length of EDFA (m)	Input power(E-6)	Input Power (In dBm)	Output Power(E-3)	Output Power (In dBm)
4	87.891	-10.561	130.886	21.169

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6	87.891	-10.561	113.033	20.532
8	87.891	-10.561	106.008	20.253
10	87.891	-10.561	101.270	20.055

TABLE2

POWER WITH THE VARYING LENGTH OF EDFA FOR COUNTER-PUMPING TECHNIQUE

Length of EDFA (m)	Input power(E-6)	Input Power (In dBm)	Output Power(E-3)	Output Power (In dBm)
4	87.891	-10.561	95.008	19.777
6	87.891	-10.561	112.629	20.517
8	87.891	-10.561	113.825	20.562
10	87.891	-10.561	1	-1

TABLE3

POWER WITH THE VARYING LENGTH OF EDFA FOR BIDIRECTIONAL -PUMPING TECHNIQUE

Length of EDFA (m)	Input power(E-6)	Input Power (In dBm)	Output Power(E-3)	Output Power (In dBm)
4	87.891	-10.561	113.020	20.532
6	87.891	-10.561	112.943	20.529
8	87.891	-10.561	110.198	20.422
10	87.891	-10.561	107.335	20.307

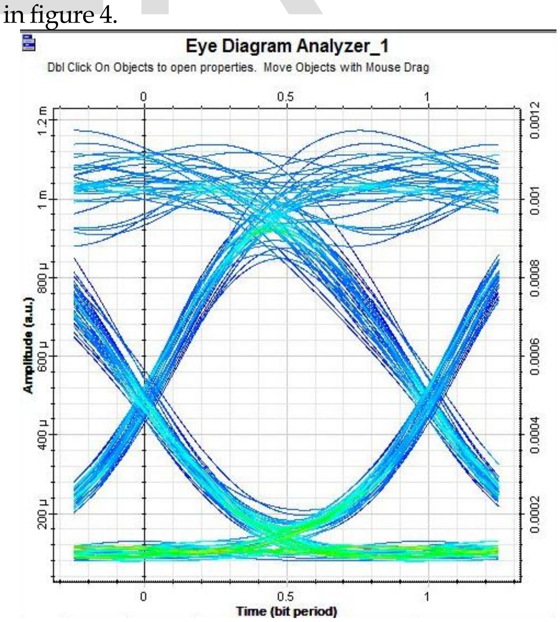
In the bidirectional pumping, power of each pump laser is maintained to be 100mW i.e. 100mW through co-coupler and 100mW through counter- coupler but total power for pumping is maintained to be 200mW for EDFA It can be observed from table 1, table 2 and table 3 that with the increase in length of EDFA the received power increase. Also it can be seen from table 2 that for counter pumping the transmission is acceptable up to 8m of EDFA length. For higher length of EDFA bidirectional pumping and co-pumping will give better results. Comparing the table 1, table 2 and table 3 it can be concluded that the bidirectional pumping gives the maximum output power with EDFA length of 10m.

TABLE 4

BER ANALYSIS FOR DIFFERENT PUMPING TECHNIQUES FOR EDFA LENGTH OF 4M TO 10M

Length of EDFA(m)	BER for co-pumping	BER for counter-pumping	BER for bidirectional-pumping
4	9.8e-20	4.25e-20	1.39e-20
6	2.33e-22	3.51e-21	2.45e-22
8	7.16e-22	1.38e-17	7.40e-22
10	2.50e-21	1	2.53e-21

From table 4, it can be observed that variation in BER of counter pumping is more than the variation in co-pumping and bidirectional pumping. So for 64 channels counter pumping is not preferred. Further, simulation results show that BER for co-pumping lies in e-20 to e-22, for counter-pumping lies in e-17 to e-21 and for bidirectional pumping lies in e-20 to e-22.
Similarly, the performance can be visualized from eye diagrams given in figure 4.



(a)

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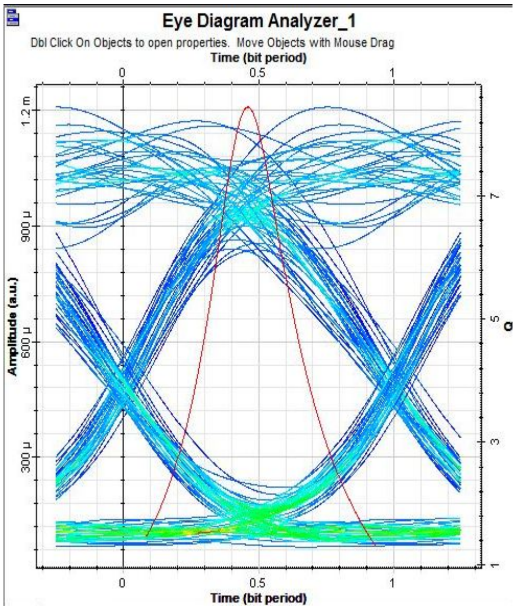
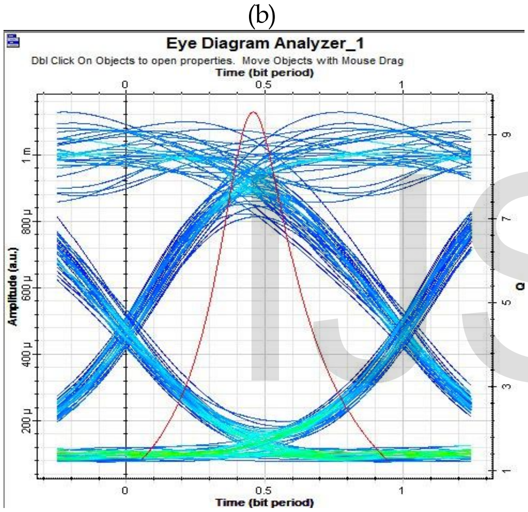


(b)



(c)

Figure 4: Eye diagram for (a) Co-pumping (b) Counter pumping (c) Bidirectional pumping

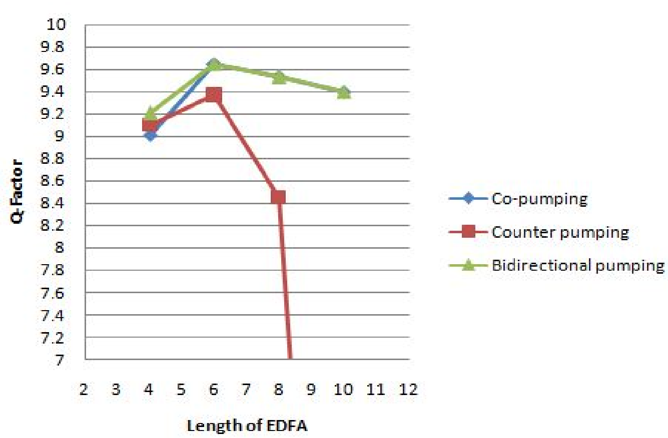


Figure 5: Q-factor Analysis for different pumping techniques

1.

Q-factor (Quality Factor) for different pumping techniques lies between 8.5 to 9.7 and BER between e-17 to e-22.

Further, from the above results, received power in case of co-pump is less for higher length of EDFA (6m-10m). After considering all the factors, bidirectional pumping for 64 channels is optimized to have the received power of about 20dBm.

4 CONCLUSION

Comparative analysis of three pumping techniquesis given in this paper i.e co-pumping, counter pumping and bidirectional in terms of BER(Bit error rate) and Q-factor for different length of EDFA(4m to 10m) in C-Band at input power of -26dBm and pump power of 200mW at 980nm pump wavelength. In case of co-pumping, received power decreases with increase in length of EDFA and BER lies in e-20 to e-22. For counter pumping, received power increases with increase in length and BER lies in e-17 to e-21, but transmission is acceptable up to 8m EDFA length. For bidirectional pumping, power decreases but provides more power as compare to other configurations and BER between e-20 to e-21 for 100mW pump lasers. So, for longer length of EDFA (8m-10m), bidirectional pumping will provide better and optimized results.

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