"Gain Flatness of EDFA in WDM System using GFF"

Dissertation Report

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To

Department of Electronics and Communication

In partial fulfillment of the Requirement for the Award of the Degree of

Master of Technology in Electronic and Communication Engineering

Under the Guidance of

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Jalandhar, Punjab (2015)

ACKNOWLEDGEMENT

With great pleasure and deep sense of gratitude, I express my indebtedness to my supervisor Mrs. Shippu Sachdeva for his invaluable guidance and constant encouragement at each and every step of my thesis work. He exposed me to the intricacies of relevant topic through proper counseling, discussions and always showed great interest in providing timely support and suitable suggestions. I express my gratitude towards all the people associated with Internet, IEEE, Elsevier and the plethora of technical websites, forums, & groups which have helped me with the study materials for my work. I would also like to express my heartfelt gratitude to my parents, brother and friends who have always supported and encouraged me to pursue my dreams.

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DECLARATION

I hereby declare that the research work entitled "*Gain Flatness of EDFA in WDM System using GFF*" is an authentic record of my own work carried out as requirements of Dissertation work for the award of degree of M.Tech in Electronics & Communication Engineering Department (ECE) from Lovely Professional University, Phagwara, under the guidance of Mr. Shippu Sachdeva during January to May 2015.

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CERTIFICATE

This is to certify that Amit Sharma has completed M.Tech dissertation proposal titled "*Gain Flatness of EDFA in WDM System using GFF*" under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of the dissertation proposal has ever been submitted for any degree or diploma. The Dissertation Proposal is fit for the submission and the partial fulfillment of the conditions for the award of M.Tech Electronics and Communication Engineering.

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ABSTRACT

In model and simulation of EDFA WDM optical network using GFF, Gain flatness of erbium-doped fiber amplifier is a key device for wavelength division multiplexing application in modern optical network system. Gain flatness of EDFA plays an important role for WDM optical application. Main purpose is to flattened gain dynamics and reduced noise figure; improve the gain unevenness for each channel in order to equalize the amplitude in WDM system. The system is simulated using optisystem software to achieve gain flatness of EDFA through optimized fiber length and pump power. By using low pass Bessel filter, GFF, input source, pumping source, EDFA, WDM multiplexer, pin photo detector, 3R generator, BER analyzer. By changing the length of fiber and pumping power value we achieve different results. By increasing pump power gain also increase by different combination of different values of fiber length and pumping power we can obtain different result.

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LIST OF ABBREVATIONS

1. EDFA---Erbium Doped Fiber Amplifier
2. GFF---Gain Flattering Filter
3. WDM---Wavelength Division Multiplexing
4. VLC---Visible light communication
5. NF---Noise Figure
6. TDM--Time Division Multiplexing
7. FDM--Frequency Division Multiplexing
8. SNR--Signal to Noise ratio
9. SOA--Semiconductor optical amplifiers
10. DCF---Dispersion compensating fibers
11. NRZ---Non return to zero
12. OFC…………………………………….…………Optical Fiber Communication

CHAPTER 1
INTRODUCTION

1.1 Fiber Communication

To fulfill the requirement of high speed data rate transfer and because of several disadvantages in wireless medium the use of optical fiber is increasing day by day. For communication to one place to another place we require transmission of information from one place to another through a medium. One of these mediums that really had a big impact on data transmission was coaxial-cable system. In coaxial-cable system we transfer our data from one place to another in the form of light. The basic principle of sending data from one place to another place by light is “Total Internal Reflection”.

First when optical fiber developed, mainly for the purpose of image transmission through a bundle of glass fiber. As compare to modern standard fibers were extremely lossy (loss>1000dB/km). However the situation changed drastically, losses of silica fibers were reduced to below (losses<20dB/km). But after some time in 1980’s losses of silica fiber becomes only 0.2dB/km in the 1.55ụm wavelength region. Except losses there is one more problem comes in uses of optical fiber, after some distance light intensity fades. To overcome this problem we use repeaters and amplifiers Repeaters are converts weak optical signal into electronic form, uses electronic signal to drive a transmitter that recreates the signal. We also use regenerators, regenerators cleans up digital signal by removing noise and distortion and regenerating a fresh signal. They have discrimination circuits that examine the time-varying signal, identifies signal and noise; clean the signal. For amplifying signal we use amplifiers. Erbium-doped fiber amplifiers (EDFA) attracted the most attention because they operate in the wavelength region near to 1.55um and can be used for compensation of losses in fiber-optics light wave system. By using EDFA attenuation can be highly reduced. In EDFA for the amplification of input signal external pump power is required. EDFA can provide high gain but the gain is not flattened, which reduces system efficiency. So, to achieve gain flatness GFF is used.

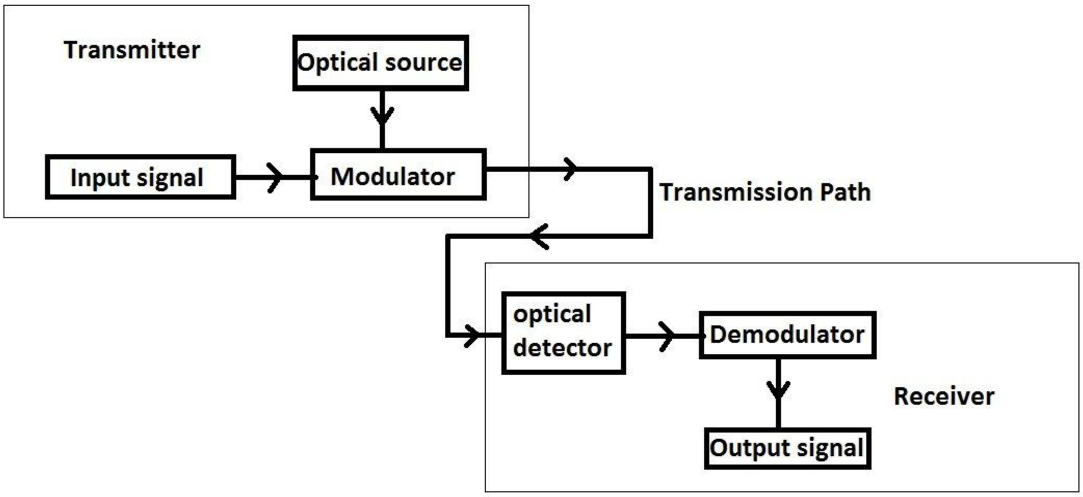

Fig.1.1 Block diagram of Optical fiber communication system

Input signal or data source transmit signal at transmitter side. The optical source is used to generate laser light signal at a certain wavelength. Modulator used to increase signal power by intermixing of two signals. The data source and the optical signal are fed to the modulator and then the resulting modulated pulse signal propagates through the transmission path which is an optical fiber. At the receiver side the optical signal is detected through an optical detector or photo detector. The detected signal then passes through the demodulator, it demodulate the modulated signal. An optical fiber is a flexible thin filament of silica glass that accepts electrical signals as input and converts them to optical signal. It carries the optical signal along the fiber length and re converts the optical signal to electrical signal at the receiver side.

1.2 Advantages of optical fiber communication

*Optical fiber cables are flexible.
*Optical fiber cables are fire proof.
*Optical fiber cables are cheaper than conventional wires.
*Optical fiber cables signal can propagate longer distances without any regeneration of signal.
*Optical fiber cables provide good speed and bandwidth, and easily upgrade for high speed and high bandwidth.
*Optical fiber cables can use it for duplex communication, bidirectional transmission from receiver to transmitter or transmitter to receiver.
*Electromagnetic interference does not affect optical fiber as they carry light.
*Chances of cross talk are very less in optical fiber cables.
*Optical fiber can support bandwidth of up to 40Gbps to 100Gbps.

1.3 Optical Amplifiers

Amplifiers which used to amplify optical signals are called optical amplifiers. Main disadvantages comes in uses of optical amplifier is it suffers from various losses like fiber attenuation losses, fiber tap losses and fiber splice losses. These types of losses create difficulty to detect the signal at the receiver side. So in order to transmit signal over a long distance in a fiber (more than 100km) it is necessary to compensate the losses in the fiber. For amplification of optical signal first it converted into electrical signal then amplified and then reconverted to optical signal. This method was complex and costly. Optical amplifiers allowed the signal amplification in optical domain, no need to first convert it into electrical signal than optical. It saves time and cost.

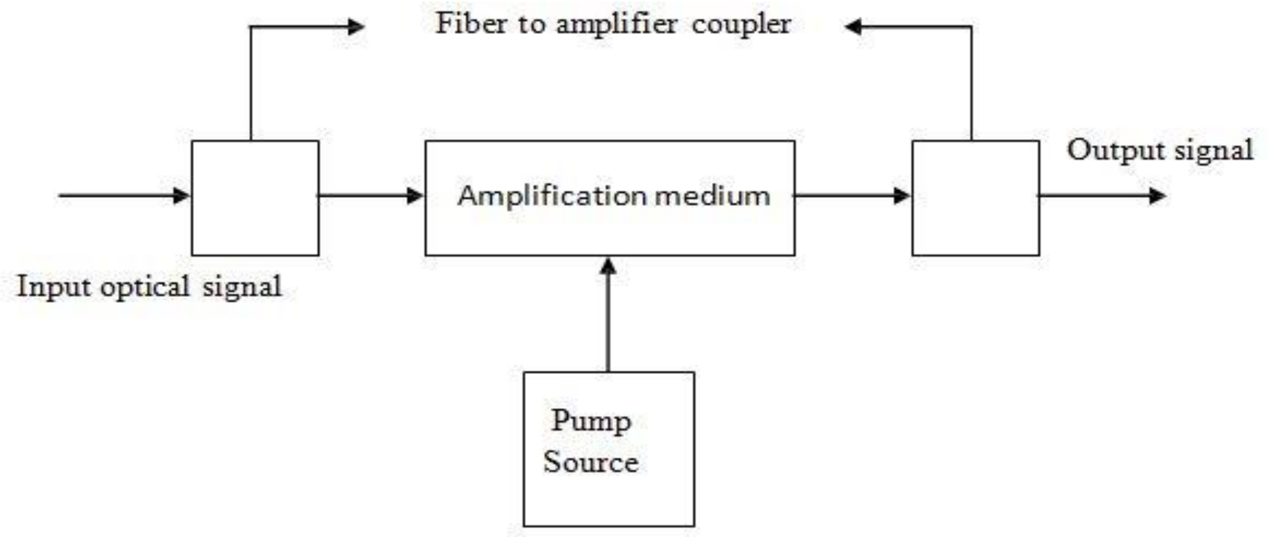

Fig.1.2 Block Diagram of basic optical amplifier

1.4 Wavelength Division Multiplexing

Time division multiplexing is not use in optical system because in time domain it is very difficult to produce signal for few second. So Frequency division multiplexing is used for multiplexing the signals. WDM technique involves FDM technique. By producing different wavelength light signal simultaneously. So WDM is the technique of sending signals of several different wavelength of light into the fiber simultaneously. To send or receiving signal simultaneously we use Bi-directional transmission over a single fiber length for transmitter and receiver. By WDM technology we can multiplexes multi optical carrier signals on a single optical fiber by using different wavelength of laser light to carry different signal. WDM is an efficient way to increase the capacity of optical system by sending multiple signals simultaneously.

1.5 Erbium Doped Fiber Amplifiers (EDFA)

In 1964 the nonlinear phenomenon of stimulated Brillouin scattering was first observed. SRS and SBS are similar because the generation of the stoke wave take place in both. When silica fiber doped with active erbium ions then the gain medium produce is called erbium doped fiber. EDFA amplifiers can work on both bands C-band and L-band simultaneously. So EDFA is very useful for wavelength division multiplexing systems. Acoustic wave can describe the process of stimulated brillouin scattering as a nonlinear interaction between the stoke field and the pump power. The pump field generates an acoustic wave through the process called electrostriction. The acoustic wave in turn modulates the refractive index of the medium. The multi-wavelength source can be realized using many methods. Some approaches to realized multi-wavelength sources are multi wavelength Brillouin fiber laser, multi wavelength Brillouin–Raman fiber laser, Brillouin-erbium fiber laser, multi wavelength erbium-doped fiber laser, multi wavelength Raman fiber laser and multi wavelength fiber optical parametric. There are several advantages of multi-wavelength Brillouin-erbium fiber laser are low threshold and multi wavelength generation at output.

1.5.1 Basic EDFA Design

Basic design of erbium doped fiber amplifiers consists of two isolators, a laser diode and a length of erbium doped fiber. Input signal and pump signal is intermixed with the help of wave length multiplexer. Then the output signal propagates in erbium-doped fiber for amplification. Two isolators are used to minimize the effect of backward pumping. The length of the Erbium Doped Fiber depends upon the input signal power, pump power, Er^{3+} ion density and the signal and pump wavelength.

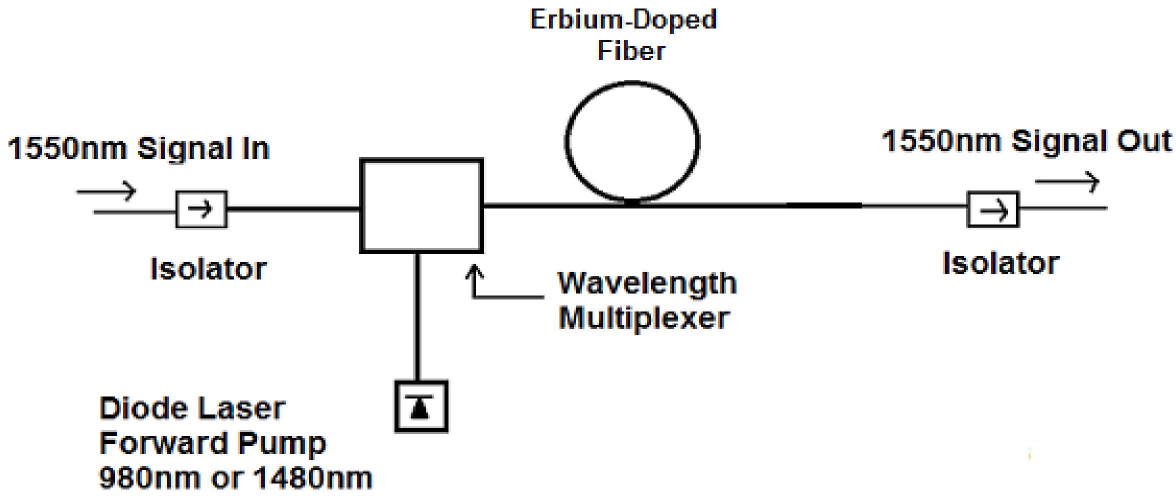

Fig.1.3 Basic Block diagram of an EDFA

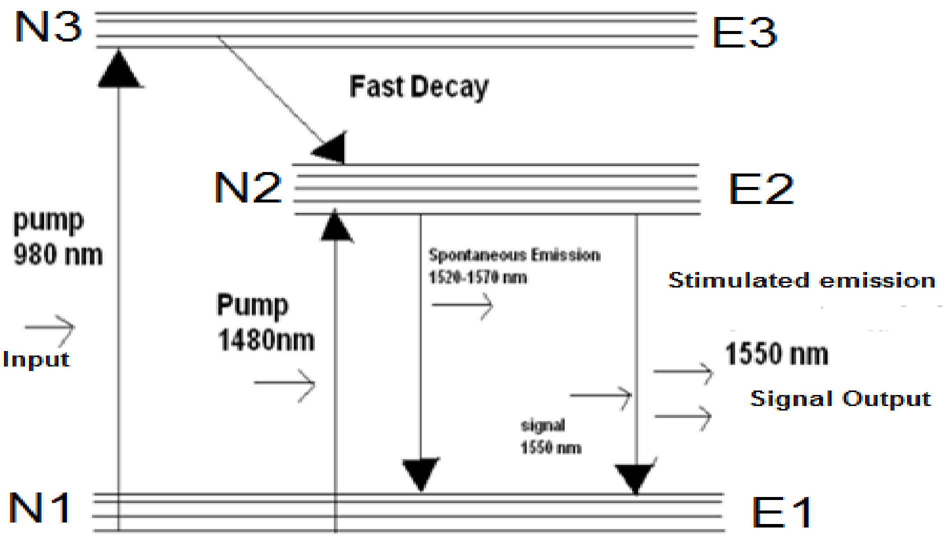

Fig. 1.4 Three level energy diagram of Er^{3+} ions

1.6 Pumping Techniques

For amplifying or increasing the power of input signal, every amplifier required pump power. There are three types of pumping techniques which is mainly used in the Er^{3+} ions from the ground state to the upper states.

1. Forward Pumping.
2. Backward Pumping.
3. Bi-directional Pumping.

1.6.1 Forward Pumping

In forward pumping the input signal and the diode laser forward pump signal are combined by wavelength division multiplexer. After intermixing of signal, output signal is send to fiber. Inside the fiber pump energy transferred and signal is amplified. Isolators are used to make sure that the signal will travel only in one direction.

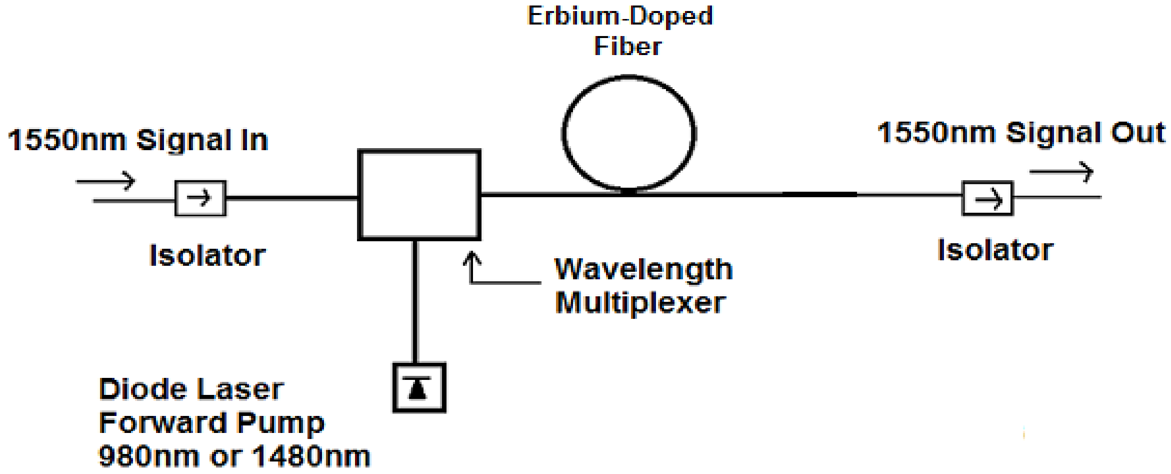

Fig.1.5 Forward Pumping.

1.6.2 Backward Pumping

In Backward pumping the input signal is given to fiber. After propagating inside fiber input signal and pump power signal is intermixed by wave length multiplexer. The direction of pump signal and input signal is not fixed. They can propagate in any direction.

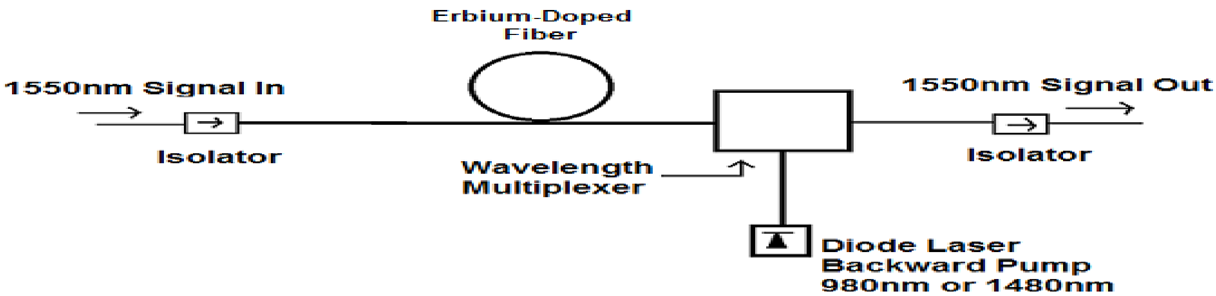

Fig.1.6 Backward Pumping.

1.6.3 Bidirectional Pumping

In Bi-directional pumping the input signal and pump signal intermixed by wave length multiplexer, then it travels inside fiber. After fiber input signal and new pump signal again intermixed by wave length multiplexer. There are two pump signals that travel inside the fiber.

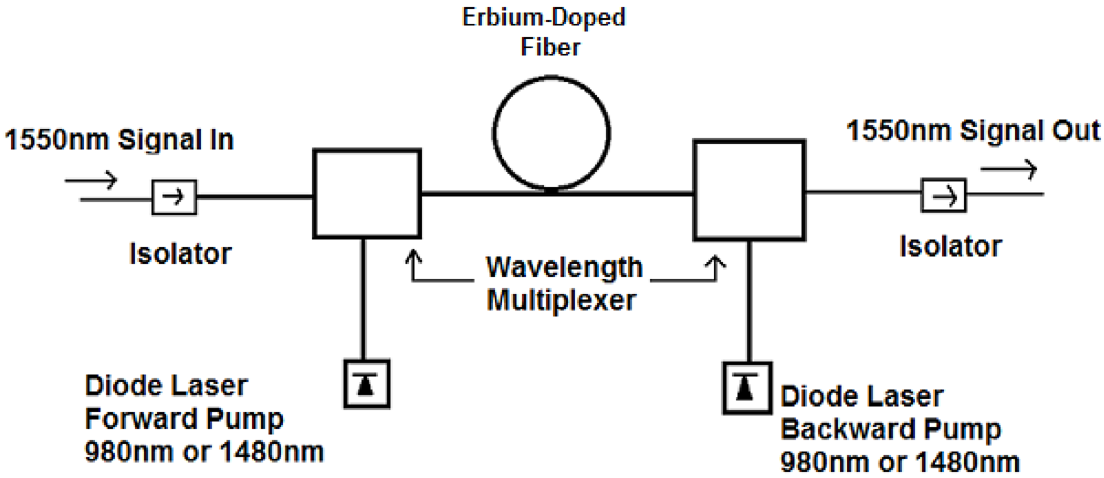

Fig.1.7 Bi-directional Pumping.

CHAPTER 2

SCOPE AND OBJECTIVE

2.1 SCOPE OF THE STUDY

To fulfill the requirement of high speed data rate transfer and because of several disadvantages in wireless medium the use of optical fiber is increasing day by day. But there are several limitations of OFC like the signal attenuation. By using EDFA attenuation can be highly reduced. There is no need to implement basic design physically; first system is simulated on optic-system and then can be implemented practically with only some minor changes in results due to environmental condition. This saves time and cost of implementation. With exponential growth in communication, the need high speed and reliable communication system has also increased. Wavelength division multiplexing (WDM) provides a convenient method for increasing the capacity of an optical system. WDM utilizes the vast optical bandwidth of a SMF. So a lot of research is going on different types of WDM systems by placing optical channels closer to each other.

The main problem in WDM system is noise and gain. So the main purpose of study in optical system is to minimize the noise figure and increase gain of the system.

2.2 OBJECTIVES OF THE STUDY

1. To study performance of the EDFA WDM systems using different fiber length.
2. To analyses the performance of EDFA WDM system using different pump power.
3. To compare the results of EDFA WDM system for different values of fiber length.
4. To analyses and compare the overall gain and gain flatness of the system.

CHAPTER 3

Literature review

The literature reviews of the proposed topic have been studied thoroughly from various books, Journals, IEEE Publications.

Following are the most important papers that have been studied compressively.

3.1 National and international Journal:

1-P.NagaSiva Kumar and A.Sangeetha in 2013 obtain the gain non-uniformity for each channel in order to equalize the amplitude gain in WDM. Check the possibility of data can be transmitted with high superiority and less number of errors calculated using SNR and BER equations theoretically. They demonstrated a dual stage L-band EDFA where the pump power, which was used to excite all the erbium ions, was distributed to two different stages with different length of EDF. They divided pump power in two parts. First 50% of the pump power was used to pump the first 10 meter EDF and remaining half was used to pump the 23 meter EDF. L-band amplified input signal produced a flat gain of less than 3 dB.

2-Liu Kaixian and Du Jaun in 2009 EDFA with some advantages of high gain, low noise and large bandwidth and disadvantages of uneven gain. This uneven gain surely reduced effective transmission bandwidth and system performance. EDFA gain flattering based on chirped fiber Bragg grating, and provides flat EDFA output gain. Numerically result shows that gain unevenness reduced to below 0.2 dB. They theoretically analyzed the basic characteristics of chirped fiber grating, and provided corresponding relation between chirped volume, variable, length and other parameters of chirped fiber gratings and refractive index. According to ASE spectrum output from EDFA, the design of uniform chirped FBG, it makes the reflection spectrum of FBG have the same distribution characteristics with EDFA output ASE spectrum. The output light becomes flattening after transmission by the gratings, with unevenness of gain spectrum lower than ±0.2dB in the range (1525-1560nm).

3-N.A. Cholan et al in 2013 compare four wave mixing of Brillouin-erbium fiber laser with enhanced output uniformly is demonstrated and its performance with or without the assistance of

FWM. The presence of four wave mixing effect is proven by anti-stokes wave. This scheme is flattening the multi wavelength output. The peak power difference is between 5.65 & 8.32 dB for the case of without FWM, and 3.55 & 5.6 dB with FWM. The presence of FWM in the fiber was justified by the generation of anti-Stokes.

4-Mrinmay Pal et al in 2008 calculated gain flatness for 16-ITU-T channel amplification at C-band using GFF to get the flat gain variation ±0.5dB for -20dBm/ch input signal power. Gain variations are studied by varying the input signal levels from -8dBm to -20dBm. By maintaining a good relation between pump power and EDFA length gain of 20±0.5dB is achieve using AGC. 15 out of 16 channels are observed ±0.5dB gain variation. The gain value was measured for different pumping power and it was showed that bi-directional pumping manifested the particular loss-spectrum of GFF in chirped fiber. Amplification is fixed at -20dBm/ch and obtains the gain value of 20±0.5dB. Gain variation is seen by changing the input signal levels.

5-Amit Sharma and Shippu Sachdeva in 2015 achieve gain flatness of 0.76dB and reduce NF using GFF in WDM system. EDFA amplify input signal by intermixing of input signal and pump power into doped fiber. GFF is used to achieve flat output gain. Gain is increase as pump power increase and vice versa, but gain is not flatten by varying pump power and EDFA length best result found at EDFA length 5m and pump power 82dBm.

6-Deepika Verma and Santosh Meena in 2014 calculated gain flatness and bit error rate improvement for an EDFA in WDM system, to improve the gain unevenness for each channel in order to equalize the amplitude in a wavelength division multiplexing (WDM) system. They use Chebshev filter, power pump, fiber length and tuning numerical apertures. By varying the pump power at constant input power they observe by increasing pump power output power also increase but at pump power 150mw gain flatness is very high which is not good for EDFA-WDM system, at pump power 100mw there is not equalized gain for all channels. They conclude optimum result lies between pump power 100mw and 150mw, then they conclude the optimized value is measured for 120mw pump power and fiber length 7.1m they get the gain flatness 0.38 and noise figure is 6.8db.

7- Shweta Bharti in 2014 give model to represent EDFA flattened gain dynamics and reduced noise figure is useful in network reconfiguration and Multi-vendor networks. She use EDFA, WDM multiplexer, GFF, for simulation on optisystem 7. She uses reference pump power of 150mw to find out the optimal length and varying the length of the EDF. The optical length is 10m because maximum output power is obtained at 10m and after that output power is going to be reduce. At constant optimum length 10m obtained input power, output power, gain, Max Q factor, Min BER, and Eye height, noise figure with varying pump power. When pump power is increase then output power and gain also increases with it, but noise figure has been decreased with the increased pump power. In WDM system integrated with EDFA and GFF gives optimized Q-factor and output peak power, also provide flat gain over a large dynamic gain range, low noise, high saturation output power, and stable operation with excellent transient suppression.

8-Paramjeet Kaur et al in 2014 the proposed model consist of an isolator, pump source, erbium fiber and WDM coupler. It simulates various characteristics such as amplified spontaneous emission, minimum gain, maximum gain, average gain, noise figure, gain flatness etc. Their result shows that the optical amplifier is to be used for amplify the signal and basically design an optical amplifier to increase the level of the input signal and found optimum parameters for transmission of data. In their paper wavelength division multiplexing technique is used for the multiplexing with input signal, the range of the optical amplifier is basically 1550-1620nm. It can be used only up to 10-30m.

9-Kamalbir Kaur and Kulwinder Singh in 2013 analysis of 16-channel WDM system using Erbium Doped Fiber Amplifier by varying EDF length and wavelength in 16-channel WDM system and the performance has been evaluate in terms of gain, output power, noise figure and bit error rate. The length of EDF is varying from 2 to 50m, pumping power ranging 100-800mw at a constant input power-26dbm. The maximum output power is attained at 10m length of amplifier. The wavelength increases, the gain also increases but after reaching at the saturation point, it start decreasing, the wavelength increasing, this ASE noise get reduced ions into EDFA. This reduction in ASE leads to increases in the signal to noise ratio (SNR) at the amplifier output and hence the noise figure decreases. They get minimum amplifier noise figure (8db) at 1554nm wavelength the pump power is 800mw.

10-M.M.Ismail et al in 2012 design a simulation of WDM Optical Network in terms of length and pump power using Optisystem software to achieve gain flatness, BER (Bit error rate), and noise figure of EDFA through optimized fiber length and pump power. They varying pump power and fiber length at a constant input power which is -26dbm. They use the reference pump power is 120mw with different fiber length, They find a suitable length of fiber of 8m because at 8m the output power gave maximum value at the reference power. Then they fixed fiber length and varying pump power. The increase of pump power will increase the output power at each meter of the length. For each of the pump power, the output power increase and decrease after reaching a maximum value. The output power of 288.603mw or 24.6dbm and average noise figure of 7.544db for 150mw and 6.757db for 500mw were obtained from the simulation.

11-Farah Diana Binti Mahad and Abu Sahmah Bin Mohd Supa in 2009 correct the gain non-uniformity for each channel in order to equalize the amplitude gain in a wavelength division multiplexing (WDM) system. they use different fiber length and pump power to achieve gain flatness of EDFA through optisystem software. They varying fiber length and pump power at a constant input power of -26dbm, they observe for a given pump power, the output power increases in initial stage and tends to decrease after the fiber length was optimized and remain almost constant. At pump power of 10mw has very low gain and high noise figure while the pump power of 40mw has high gain and less noise but yield the highest gain flatness of 1.72db. Mean the pump power of 20mw and 30mw has an acceptable noise figure of 5db but at pump power 30mw yield higher gain flatness of 1.14db as compared to 20mw. They observe the best gain and noise figure was found to be at the optimum pump power of 20mw with a low gain flatness of 0.89db at c-band.

12-Herotaka Ono et al in *2013* EDFA with a wide gain range and small noise figure (NF) variation is analyzed numerically and demonstrated experimentally. The EDFA can change the total erbium-doped fiber length by selecting six combinations of three EDFs with optical switches (SWs). The numerical calculation of the NF and the pump power using the analytical model of an EDFA indicates that such a variable gain EDFA has an advantage over a conventional multi-stage EDFA in terms of NF variation and required pump power. The concept and advantage of the EDFA in terms of NF and pump power qualitively and analyzed the NF and the pump power characteristics for the EDFA numerically by using an analytical model of an EDFA.

13-B.Nagaraju et al In this paper they discussed about the fabrication of symmetric core fabrication of an asymmetric twin core fiber directional coupler for gain EDFA. In this the basic idea was to obtain inherently gain flattened (EDFA). In this paper they conclude that an inherently gain flattened fiber amplifier using asymmetric twin core fiber in which one of the cores in doped wit ER3+ while other core is un-doped, a theoretical gain spectrum flatted with +-1db over 32nm of bandwidth (from 1530 nm to 1562nm) .

14-S.Semmalar et al In this paper they describe EDFA with different fiber length using single pumping power with the different wavelength and the result are plotted with an influence of various pump power. The Erbium doped fiber amplifier's gain which appears in the signal to noise ratio expression is computed from the simulation. The resulting models accurately represent EDFA optimized gain. Based on above discussion they concluded that an EDFA with single pumping has been modeled and simulated successfully with optimized gain and noise figure is reduced, they have shown that the proposed model of an EDFA with single pumping was successfully simulated using WDM.

CHAPTER 4

RESEARCH AND MYTHOLOGY

4.1 Working of EDFA GFF with WDM

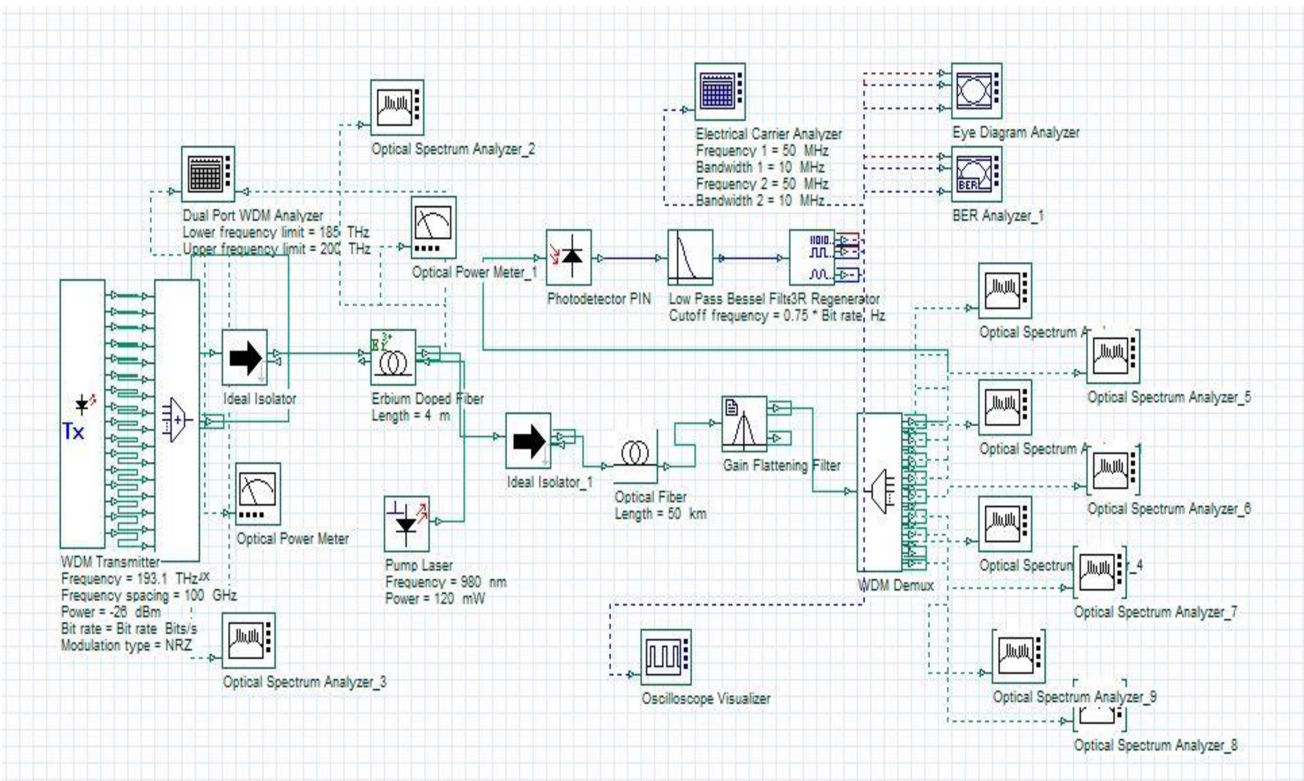

Fig.4.1 Block Daigram of EDFA GFF model with WDM

Block Diagram contain a 16 channel WDM Transmitter which give input power to the circuit, frequency range starting from 185.057 THz and frequency spacing = 60GHz, input power is -2.6dbm, modulation type is NRZ (non-return to zero) is used. Then ideal mux is used to convert many input to one output here 16 input signals to one output signal. At output of ideal mux an optical power meter analyzer and Optical Spectrum Analyzer is used, optical power meter is used to calculate the output power of signal. And optical spectrum analyzer is used to calculate noise and power of signal. Then the combination of ideal isolator, Erbium Doped Fiber (EDF), Pump Power is called Erbium Doped Fiber Amplifier (EDFA).

EDFA consists of laser diode which is used as pump and wavelength selective coupler to multiplex or combine the signal and pump wavelength together, so that they can propagate simultaneously in the fiber, they can propagate in the opposite or same direction. The optical signal is then combined with diode laser through a wavelength multiplexer. The combined signal is then passed through EDF and gets amplified. After EDFA optical signal is given to receiver part through optical fiber cable here optical fiber length is 50km. Then signal given to Gain Flattering Filter (GFF), GFF flatten the gain profile in optical amplifiers by selectively removing excess power. GFF is also known as gain equalizing filters, are used to flatten or smooth out unequal signal intensities over a specified wavelength range. Output of GFF is given to ideal de-mux here 1 into 16 de-mux is used which convert 1 input signal into 16 output signal. At one of the output pin of de-mux photo detector pin is used which convert optical signal to electrical according to their intensity. Then output of photo detector pin is given to low pass Bessel filter which pass only low frequency then its cut off frequency and stop all frequencies signal which have greater frequency than its cut off frequency. Then 3R regenerator is used which cleans up digital signal by removing noise and distortion and regenerate a fresh signal. They have discrimination circuits that examine the time-varying signal, identifies signal and noise; clean the signal. Then Eye Diagram Analyzer and BER analyzer is used to measure Eye Diagram, Q factor, Min BER, Threshold, Height of Eye, BER Pattern. Then 8 optical Spectrum Analyzer is used to analyze power and noise of signal which is placed at alternative pin 1 to 16 de-mux.

Chapter 5

Results and Discussion

5.1 Results at Standard Value

The pump power is bound between 70mw and 100mw while the fiber length is bound between 2 and 6 m. The output power is measured by varying pump power and fiber length at a constant input power -26dbm.The output power increase as the pump power increases. For a given pump power, the output power increases in initial stage and tends to decrease after the fiber length was optimized and remain almost constant .Frequency range starting from 193.1THz frequency spacing of 100 GHz. At different fiber length value of gain flatness is moving between 1 to 3 dbm. At these pump power and EDFA length high gain is achieve up to 32dBm. But Gain is not flattened. By varying pump power and EDFA length different result was obtained.

Pump Power	Gain Flatness	Noise Figure		Quality Factor
		Max	Min	
70	30.64±0.81	5.32	4.92	21.91
75	30.96±0.79	5.27	4.88	22.52
80	31.36±0.77	5.23	4.85	21.76
82	31.37±0.76	5.21	4.84	22.87
90	31.79±0.81	5.16	4.79	21.23
100	32.26±0.86	5.10	4.75	21.78

Table 5.1 Gain Flatness at different pump power

From the above table clearly shows that as we increase pump power from 70mw to 100mw first gain flatness start decreasing to 82 mw as we further increase pump power from 82mw gain flatness start increasing we obtain optimum result at 82mw. In case of noise figure as pump power increase noise figure start decreasing. Quality factor maximum at pump power 70mw is 21.91 and minimum at pump power 90mw is 21.23 but best overall result obtain from above table is at pump power 82mw with gain flatness 31.37±0.76 dBm, noise figure maximum 5.21 and minimum 4.84, and quality factor 22.87.

EDFA Length	Gain flatness	Noise Figure		Quality Factor
		Max.	Min.	
2	21.26±1.61	3.2	3.1	12.5
3	27.92±1.76	3.5	3.3	25.07
4	30.47±1.31	4.1	3.9	24.02
5	31.37±0.76	5.2	4.8	22.87
6	31.66±1.34	6.5	5.8	19.58

Table 5.2 Gain Flatness at different EDFA length

From the above table as we increase the EDFA length gain is also increase, but gain is not flat. First gain and gain flatness start increasing as we increase EDFA length. But after some values it start decreasing. The best value of gain flatness is found at EDFA length 5m is 31.37±0.76 dBm. Noise figure also increase as we increase EDFA length. Quality factor minimum at EDFA length 2m and maximum at EDFA length 3m, from above table optimum result found at EDFA length 5m.

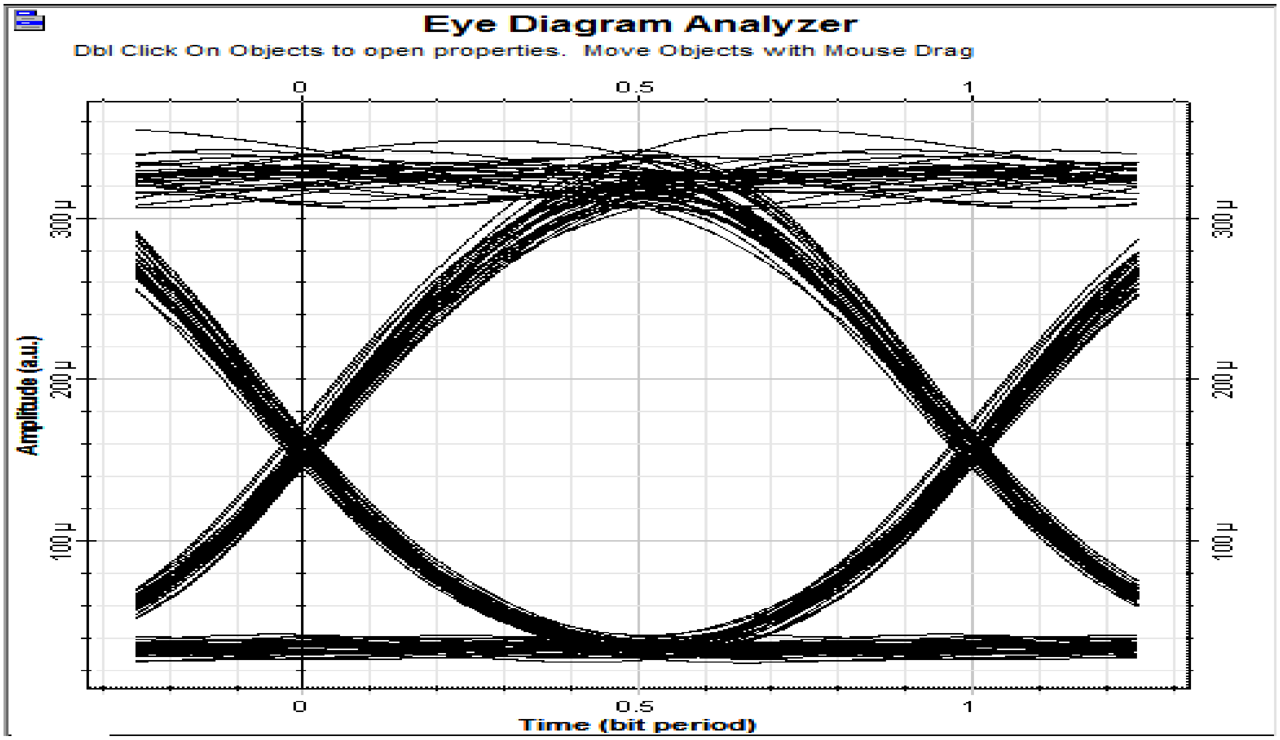

Fig.5.1 Eye Diagram

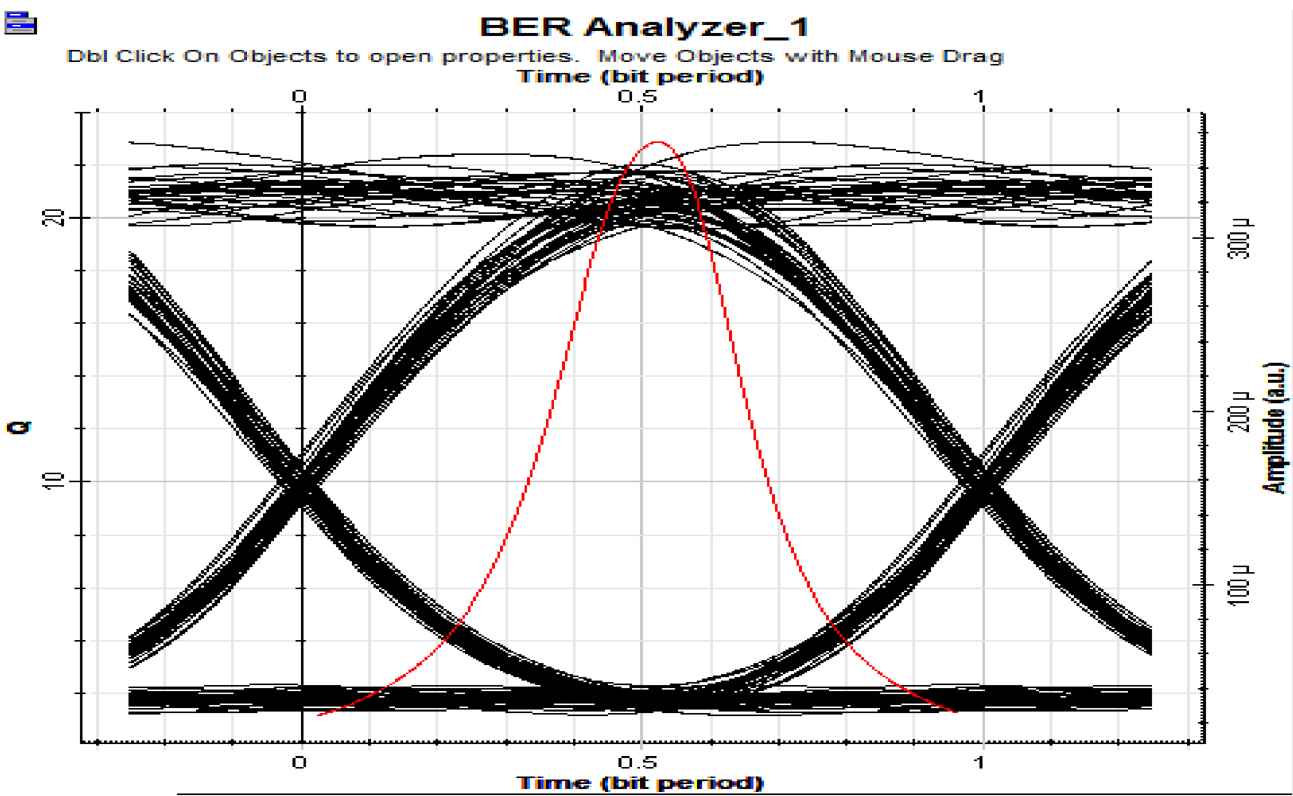

Fig.5.2 BER Analyzer

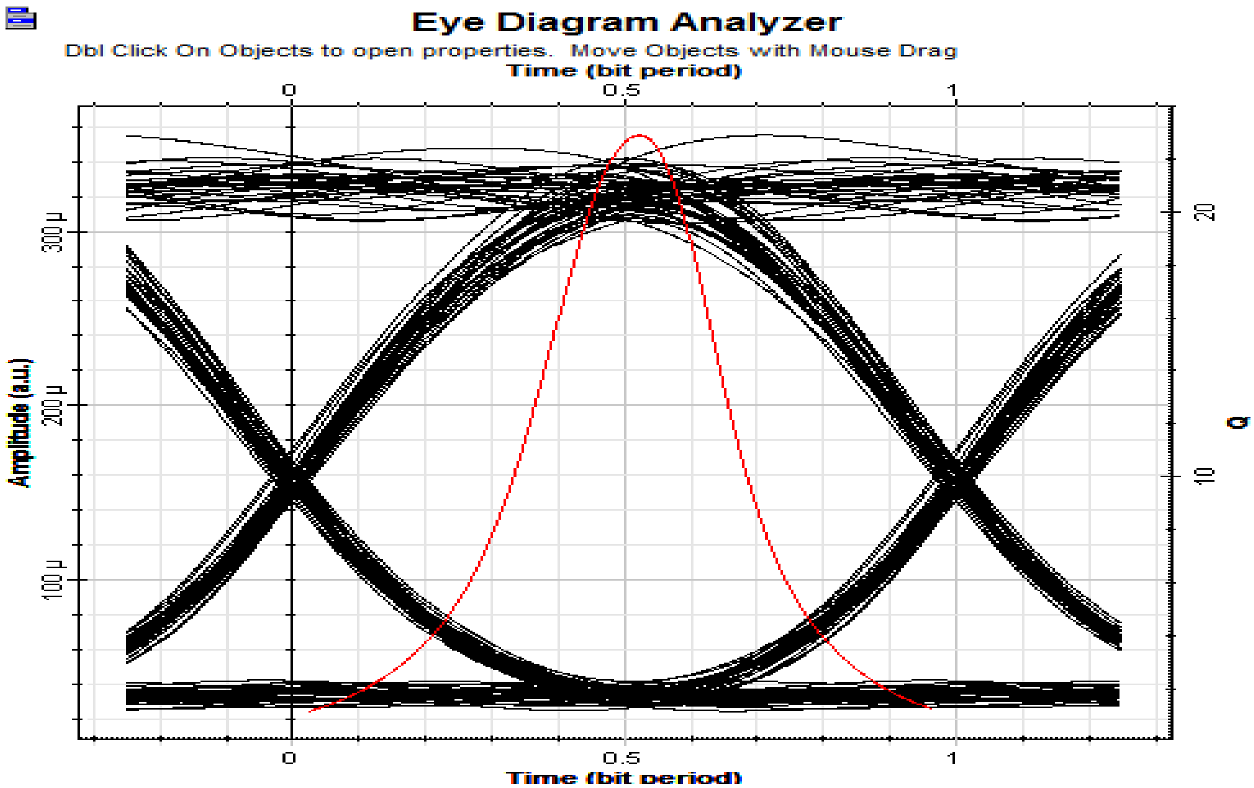

Fig.5.3 Quality Factor

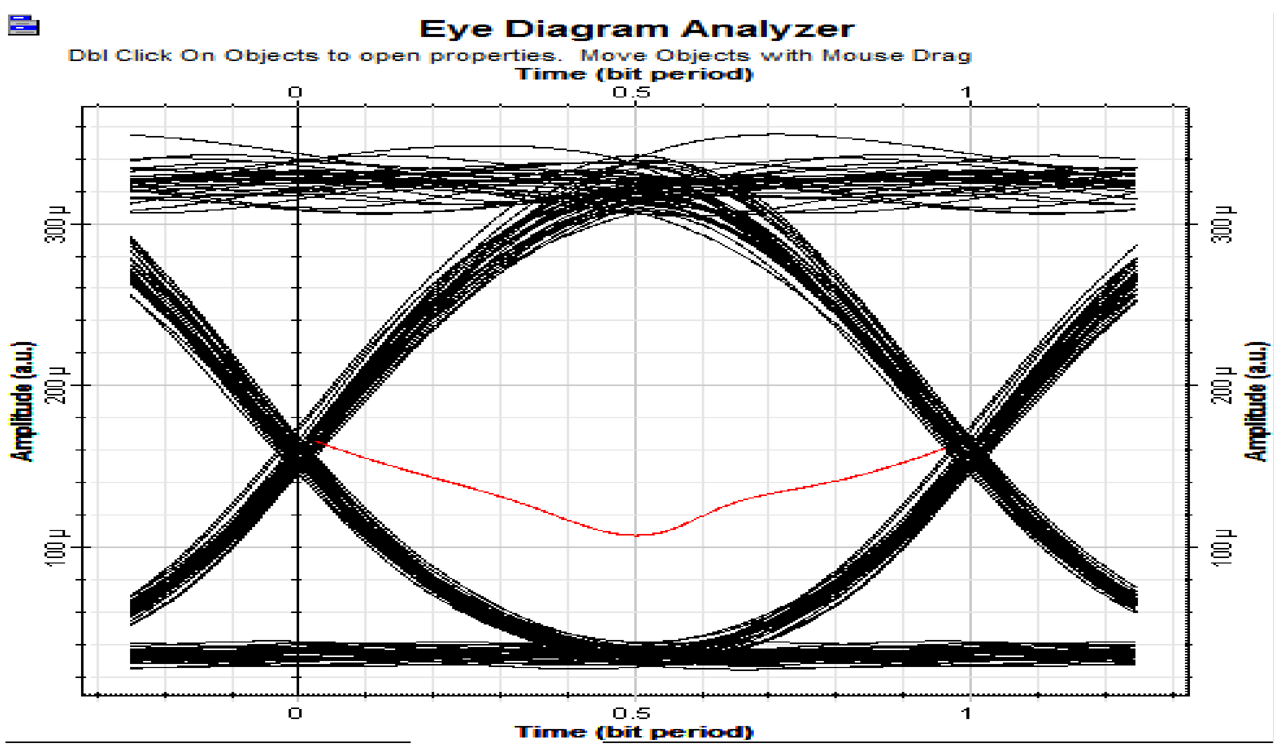

Fig.5.4 Threshold value

Eye diagrams show the effect of Inter symbol Interference (ISI). Opening of eye tells us about the ISI effect. As the value of eye height increases then the effect of ISI decrease and vice versa. Above figures sows the value of Eye height, Min BER, Threshold value and maximum value of quality factor. Eye diagrams with Eye height 0.000249885, Threshold value is 0.000107893, Min BER value 3.76636e-116 and quality factor of 22.8732.

5.2 Results at Modified standard values

Above results are calculated at standard WDM transmitter values. At standard transmitter value by varying EDFA length and pump power good result was obtain. From above result value of gain is very high but gain of all the channels is not same or we can say that gain is not flat. For achieving high gain flatness there are some changes was done in WDM transmitter parameters. A 16:1 WDM transmitter of input power of 2.6 dBm is used. The initial frequency of the transmitter is set to 185.05 THz with a frequency spacing of 60 GHz. To increase the bandwidth capacity of the system frequency range 185.05 THz to 185.95 THz is used. The pump power is bound between 70mW and 150mW while the fiber length is bound between 1m to 14m. The output power is measured by varying pump power and fiber length at a constant input power -2.6dBm.The output power increase as the pump power increases.

EDFA length	**Gain Flatness**	**Noise figure**		**Quality Factor**
		Max	**Min**	
1	2.38±0.16	-2.29	-2.45	44.47
3	5.71±0.34	-5.33	-5.87	42.57
6	6.48±0.22	-6.36	-6.51	42.54
8	6.46±0.12	-6.39	-6.52	42.74
10	6.42±0.17	-6.33	-6.50	42.54
12	6.38±0.27	-6.23	-6.51	43.2
14	6.34±0.38	-6.13	-6.51	41.78

Table 5.3 Gain Flatness and Noise Figure for different EDFA length.

Pump Power	Gain Flatness	Noise Figure		Quality Factor
		Max	Min	
70	5.22±0.13	-5.15	-5.29	43.01
80	5.67±0.11	-5.62	-5.73	41.41
90	6.08±0.18	-6.02	-6.13	43.05
100	6.46±0.12	-6.39	-6.52	42.74
120	7.12±0.16	-7.03	-7.20	42.42
140	7.70±0.21	-7.58	-7.80	40.50
150	7.97±0.23	-7.83	-8.07	39.53

Table 5.4 Gain Flatness and Noise Figure for different Pump Power.

EDFA length is fixed initially at 5m and value of pump power varies from 70mW to 150mW. The difference between pump power values is 10mW. Gain is increased as we increase pump power but gain flatness decreases as we increase pump power. Quality factor decrease as we increase pump power. Optimum results are found at pump power 100mW, now the value of pump power is fixed at 100mW and EDFA length is varied from 1m to 14m. Initially gain starts increasing from EDFA lengths 1m to 5m, but after EDFA length 5m it starts decreasing till 10m after 10m it again start increasing. But gain flatness first increases till 10m and later on starts decreasing after 10m, from this we conclude that best result is lies between EDFA lengths of 1m to 10m, optimum result found at EDFA length 6m.

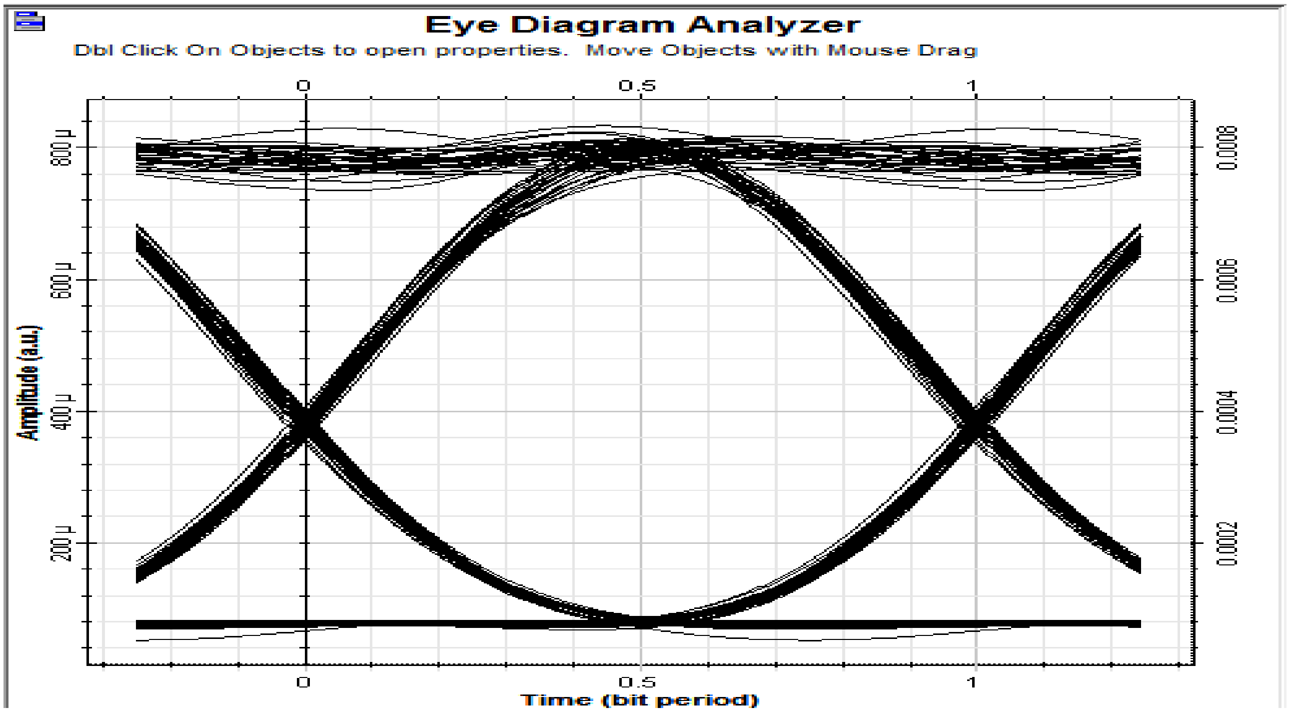

Fig.5.5 Eye Daigram

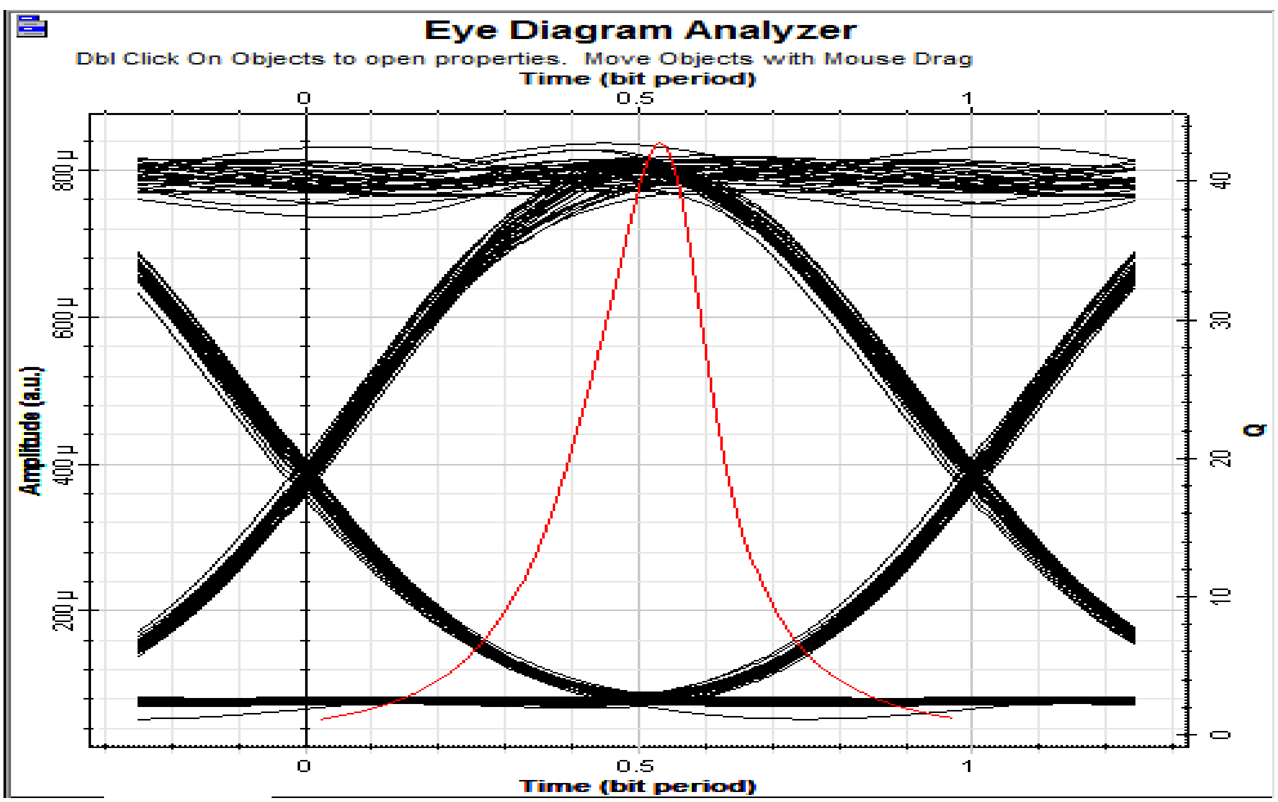

Fig.5.6 BER anlyzer

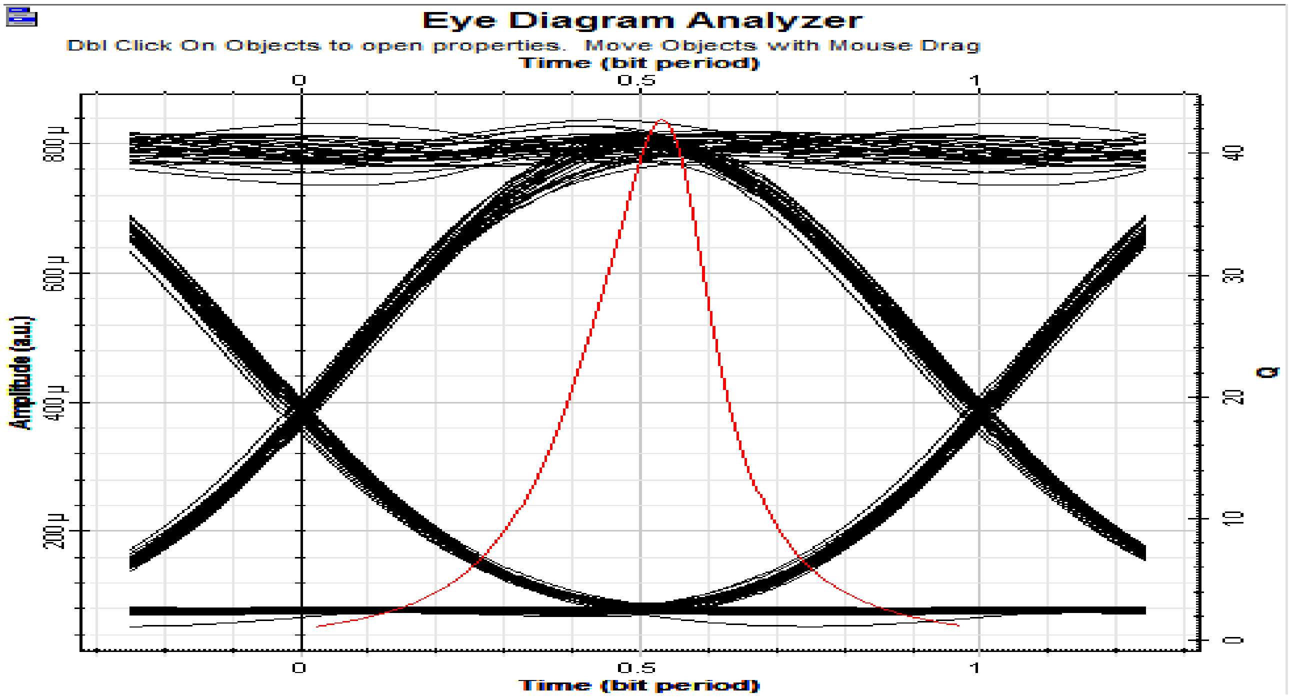

Fig.5.7 Quality Factor

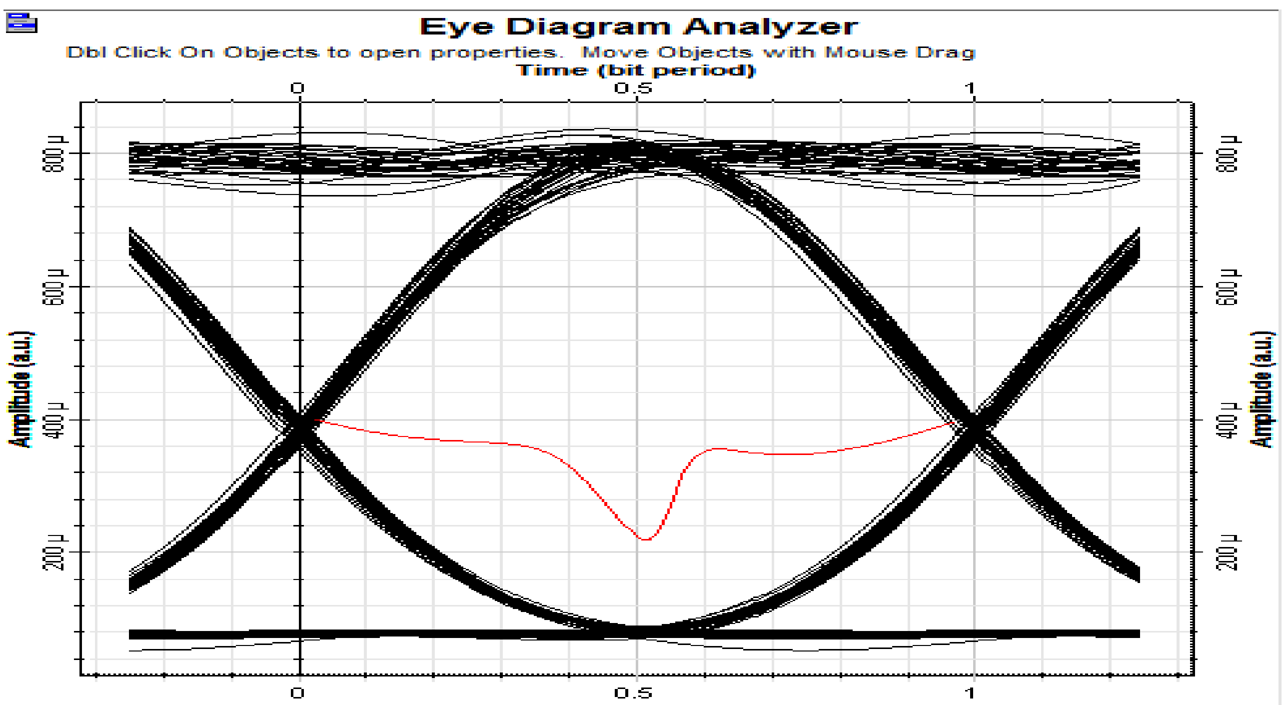

Fig.5.8 Threshold value

Above figures sows the value of Eye height, Min BER, Threshold value and maximum value of quality factor. Eye diagrams with Eye height 0.000666537, Threshold value is 0.000229423, Min BER value 0 and quality factor of 42.7455.

5.2.1 OSNR AT DIFFERENT FREQUENCY

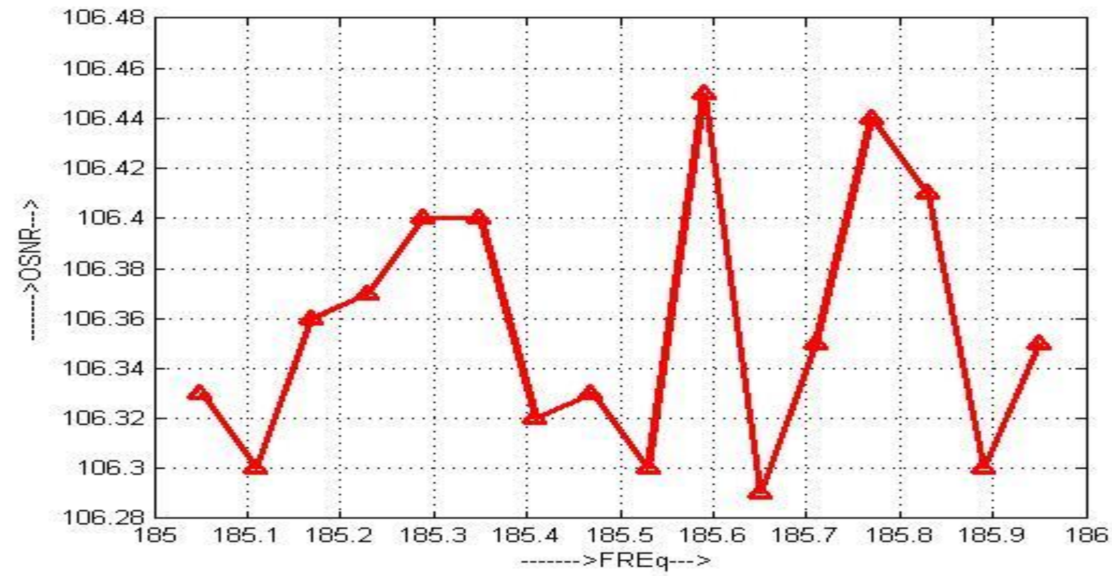

Fig.5.9 OSNR for different frequency

From above graph, maximum value of OSNR is 106.45dB at frequency 185.59THz and minimum value of OSNR is 106.29dB at frequency 185.65THz.

5.2.2 QUALITY FACTOR

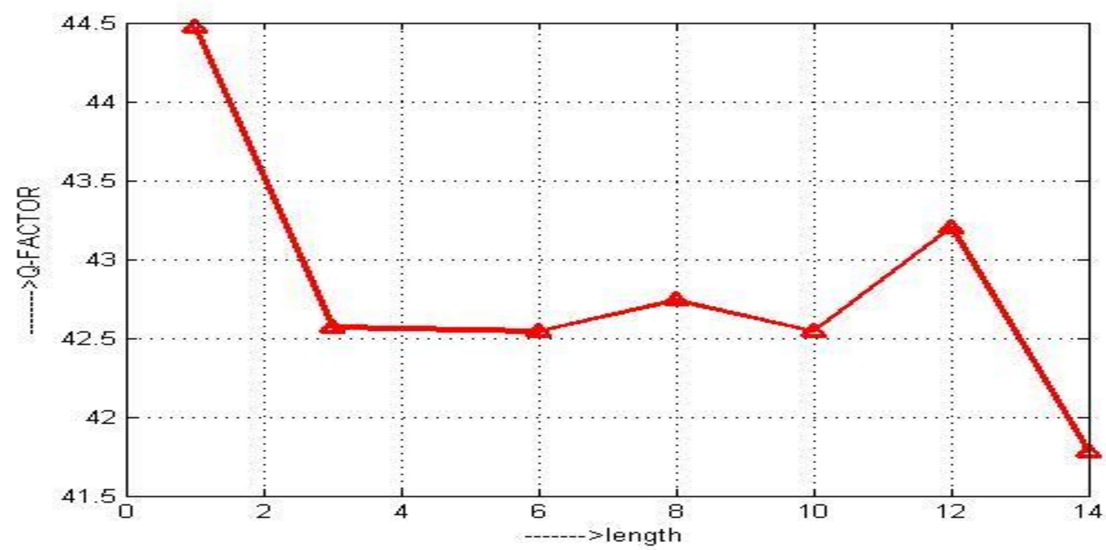

Fig.5.10 Q-factor at different EDFA length

From above graph, it clearly shows that as EDFA length increases from 1m, Q-factor value sharply starts decreasing. After EDFA length of 2m to 10m its value remains constant and only small variation can be seen, but after 10m it starts increasing than start decreasing till EDFA length 14m. Maximum value of quality factor is 44.47 at EDFA length 1m and minimum value of quality factor is 41.78 at EDFA length 14m.

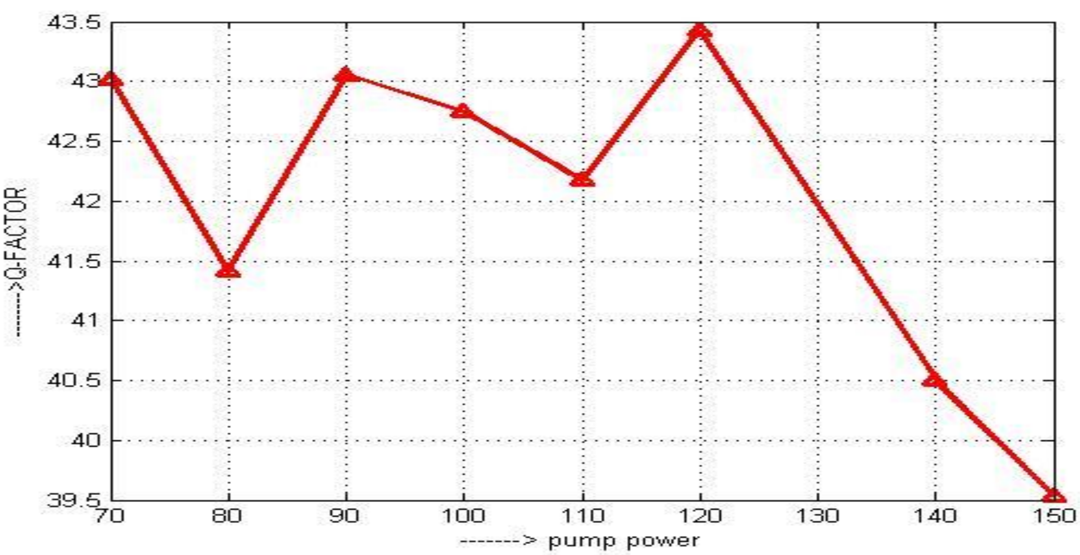

Fig.5.11 Q-factor at different Pump power

Second graph shows Q-factor value at different pumping power, from above graph, it clearly shows that quality factor value fluctuate between pump power 70mW to 120mW, but as we further increase pump power from 120m than quality factor value starts sharply decreasing. Maximum value of quality factor is 43.42 at pump power 120mW and minimum value of quality factor is 39.53 at pump power 150mW.

As we increase pump power gain is also increase but gain flatness is fluctuate. Same as in case of EDFA length as we increase EDFA length value of gain start increasing but gain flatness is first decrease from EDFA length 1m to 8m than start increasing. Optimum result is found Gain flatness 6.46±0.12 dB at EDFA length 8m and pump laser power at 100mW, noise figure minimum value at same parameters is -6.52dB and maximum value -6.39 dB and quality factor 42.74 with eye height 0.000666537.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Conclusion

The proposed model of EDFA-WDM Optical network using GFF has been simulated and studied. As shown in above results when pump power is increasing then output power and gain also increases with it, but gain is not flatten. Noise figure has been decreased with increasing pump power. The gain flatness is improved by optimize the pump power to EDFA and fiber length. By using GFF a flatten gain is obtained. The Max Q factor also increased continuously with the pump power. It can be concluded that the WDM system integrated with EDFA and GFF gives optimized Q-Factor and output peak power, also provide flat gain over a large dynamic gain range, low noise, and high saturation output power.

6.2 Future Work

Optical fiber provides large bandwidth for data transmission. Optical fiber cables are flexible, fire proof, and cheaper than conventional wires. Optical fiber cables can use it for duplex communication, bidirectional transmission from receiver to transmitter or transmitter to receiver. Electromagnetic interference does not affect optical fiber as they carry light. Chances of cross talk are very less in optical fiber cables. Optical fiber can support bandwidth of up to 40Gbps to 100Gbps. Only problem in using of optical fiber cable is gain flatness. Gain is not flat in OFC, it reduce system capability. In this thesis we are trying to improve gain flatness of system.

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