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Gain Analysis of EDF Amplifier Based WDM System Using Different Pumping Wavelength

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Abstract: *This report describes the simulation model of Erbium doped fiber amplifier (EDFA) with different pump power (250mw,300mw,up to 500mw) with optimized gain and maintained noise figure is obtained by using single pumping (backward pumping) with the wavelength 980nm and 1480nm pumping wavelength and the results are plotted with various fiber length and pump power. The performance of the EDFA based WDM system has been evaluated in terms of different parameter such as gain, gain flatness, and noise figure. The system has a wide variety of research in next generation networks. The EDFA optical amplifier system is require less input power so such systems are easy to evaluate and provide high gain and less noise figure. Many factors i.e. gain flatness, noise figure and bit error rate (BER) may influence the performance of such systems. In this research, the gain is being optimized in terms of different fiber length and pump power. The system is simulated on Opti- system software to analyze the gain flatness bit error rate and noise figure of EDFA through optimized fiber length and pump power. The gain is flattened within 39±0.25dB and noise figure<5dB for 16 channels from 1546nm to 1558nm range of wavelength with the channel spacing of 0.8nm are simultaneously operating with the single stage EDFA with a constant input power -26dB.*

Keywords: *EDFA, gain flatness, fiber length, pump power, WDM, single pumping,pumping wavelength.*

I. Introduction

Optical Amplifier is a device that amplifies an optical signal (as input signal) directly in optical form without the need of first convert it into an electrical signal. There are so many optical amplifier are used in telecommunication but here we do the gain analysis of Erbium-doped fiber amplifier (EDFA) using WDM system. Now a days, Internet services requires large bandwidth, so EDFA's are used in WDM Technology which increases the optical network capacity without affecting the cost. Wavelength-division multiplexing (WDM) is the kind of the multiplexer that is intended to use multiple number of sources that are bound to operate at different wavelengths for transmission of several independent information streams over the same fiber in simultaneous manner. The fiber transmission capacity is further enhanced using WDM. In WDM system the wavelengths over C-band and L-band are amplified to require power level where the amplification of the particular channel depends on [1] :

- Signal wavelength
- Number of signal present in system
- Input signal power

Since the WDM device need to operate at electronic speed commonly, it is easier to implement any WDM devices.

II. System Description

Erbium Doped Fiber Amplifier (EDFA) is a Optical Amplifier that uses a fiber which has been lightly doped with rare earth ion (i.e.erbium). It is uses this doped optical fiber as a gain medium to amplify an optical signal. The signal to be amplified and a pump laser are multiplexed into a doped fiber and the signal is amplified through interaction with doping ions.The EDFA having limited range (10m to 30m) [2]. The operation of standard EDFA normally is limited to 1530 to 1560 nm region, this region is known as C-band (Conventional band). For simultaneous amplification of various data channel having different wavelengths in different gain regions a single EDFA is used. Before the development of such fiber amplifiers there was no such practical method available for the process of amplification of the channels between long fiber spans of fiber optics link [3].Several methods used for the purpose of designing flat spectral gain EDFA are :

- By controlling doped fiber length, pump power and choosing proper optical notch for filters characteristics.
- By employing homogenous broadened gain medium
- By using acousto-optic tunable fiber

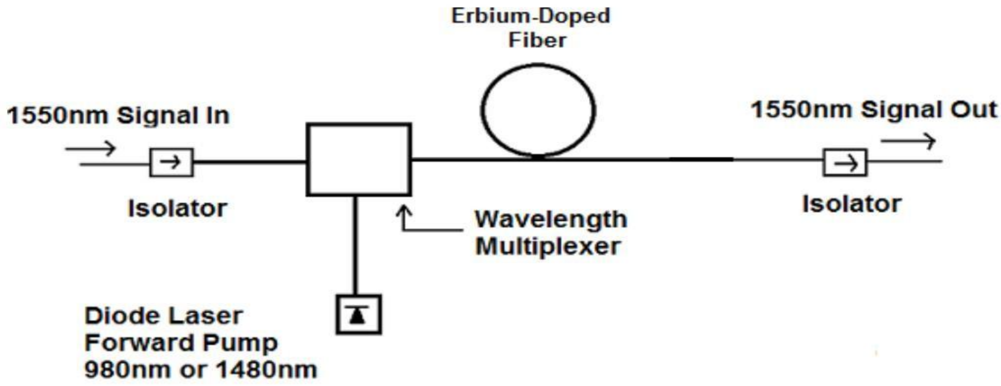

Fig. 1.1: Basic block diagram of an EDFA

EDFA-WDM system stimulated using Opti-system software to achieve the gain flatness of EDFA through optimized fiber length and pump power. The gains are flattened within 39±0.5 dB from 1546nm to 1558nm band of wavelength with noise figure (NF)<6dB for 16-channels simultaneous amplification in a single stage EDFA with channel spacing 0.8nm. The gain is optimized using a single pumping with the wavelength 980nm. The 980nm pumping yields a complete population inversion (maximum gain) at shorter amplifier lengths than 1480nm pumping. This leads to a lower amplifiers noise figure when using 980 nm pumping [4][5].

III. Motivation Of Research Work

In analyzing and designing optical network there are several methods can be used. For this EDFA (Erbium doped fiber amplifier) gain optimization for WDM (Wavelength Division Multiplexer) system optical network, used simulation approach rather than fabrication methods. Simulator allows engineers to design the most correct and efficient design before the actual optical network constructed. Moreover, able to explore the merits of other design without physically build it. Besides, by using simulation method engineers able to study problem that occur during designing the optical network. Before starts to design, need to identify the best simulators software that is suitable to design this optical network. After comparing advantages and disadvantages between Opti- system and MATLAB, Opti-system software was selected to be used in designing EDFA in WDM system. Opti- system is a comprehensive simulation package developed by Opti-wave[6]. This software enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks. A robust graphical user interface controls the optical component layout, component models and presentation graphics. An extensive library of active and passive components includes realistic, wavelength-dependent parameters. Parameters sweeps allow us to investigate the effect of particular device specifications on system performance [7][8].

The applied methodology is based on Backward Single Pumping approach. Each block in the architecture was added in the model and tested and later those blocks were assembled and were added to compose.

IV. Research Methodology

A relatively high-powered beam of light is mixed with the input signal using a wavelength selective coupler. The input signal and the excitation light must be at significantly different wavelengths [9]. The mixed light is guided into a section of fiber with erbium ions included in the core. This high-powered light beam excites the erbium ions to their higher-energy state. When the photons belonging to the signal at a different wavelength from the pump light meet the excited erbium atoms, the erbium atoms give up some of their energy to the signal and return to their lower-energy state[10].

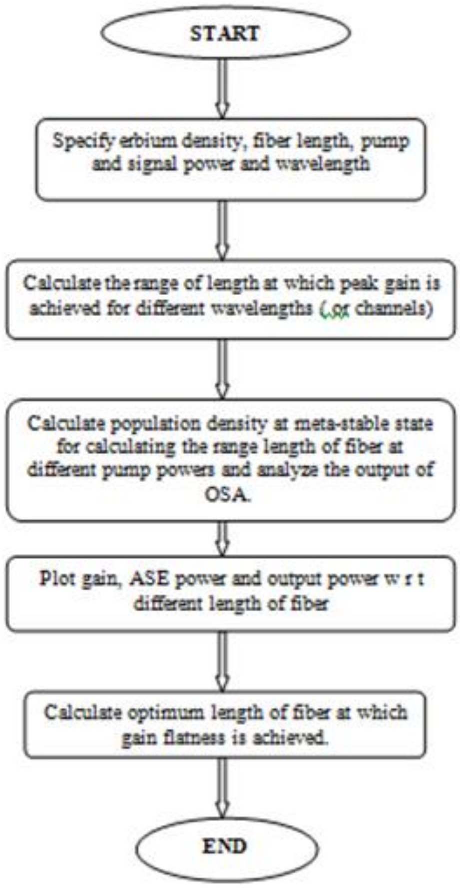

Fig. 1.2 Flowchart of EDFA amplifying process

V. Proposed Work And Result

In analyzing and designing optical network there are several methods can be used. For this EDFA (Erbium doped fiber amplifier) gain optimization for WDM (Wavelength Division Multiplexer) system optical network, used simulation approach rather than fabrication methods. Simulator allows engineers to design the most correct and efficient design before the actual optical network constructed. Moreover [11], able to explore the merits of other design without physically build it. Besides, by using simulation method engineers are able to study problem that occur during designing the optical network .The pump power is taken in a range of 250mw-500mw while the fiber length is bound between 2 to 22m. In other hand, the 16 input channels with a spacing of 0.8nm from 1546nm to 1558nm were simultaneously operated on a single fiber with a constant input power i.e. 26dBm. The reference pup power is set to be 120mw. After that it is measured at different pump power such as 250mw,300mw etc, with an increment of 50mw up to 500mw [12]. The pumping wavelength is 980nm. the reference power is set to 120mw for the measurement of different fiber length to find the optimized length of fiber for amplifier used in this system as show in table1.A suitable length of fiber is 8m is chosen as an optimum length for this system because at 8m the output power gave the maximum value at the reference power. Therefore, the gain and noise figure are measured at 8m length with different pump power as shown in Fig 1.3 [13].

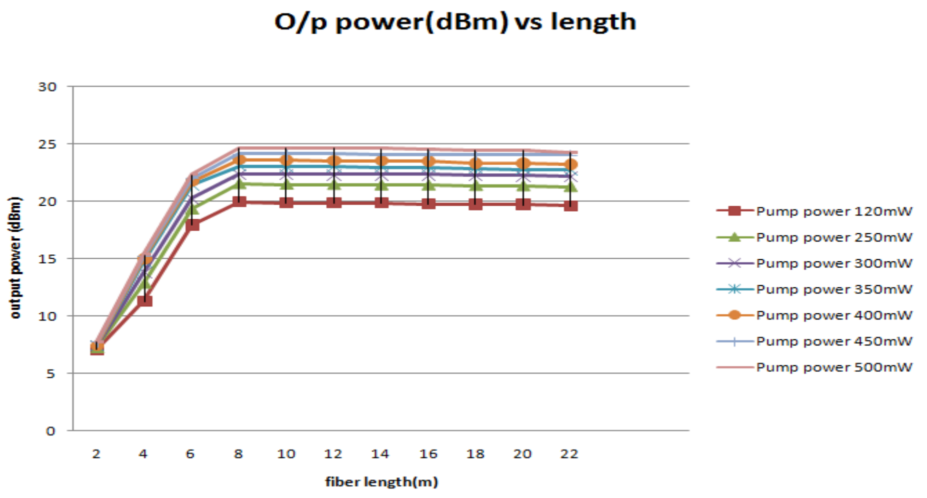

Fig1.3 Variation of output power along the fiber length for different pump powers at a constant input power
Further all the result and table of proposed work is shown below.

Pump power (mw)	i/p power (E-3)W	O/p power (E-3)W	DBm
250	21.959	168.391	21.938
300	21.959	195.521	22.647
350	21.959	227.727	23.235
400	21.959	254.099	23.783
450	21.959	277.724	24.172
500	21.959	306.653	25.557

Table 1.1 Transmitted and received power with different pump power

Wavelength(nm)	Gain (dB)	Noise figure (dB)
1546	40.13	4.82
1546.8	40.36	4.62
1547.6	40.45	4.72
1548.6	40.54	4.73
1549.2	40.65	4.76
1550	40.73	4.71
1550.8	40.68	4.65
1551.6	40.73	4.66
1552.4	40.82	4.67
1553.2	40.85	4.70
1554	40.81	4.59
1554.8	40.84	4.64
1555.6	40.80	4.59
1556.4	40.71	4.56
1557.2	40.64	4.56
1558	40.60	4.44

Table 1.2: Gain and noise figure with respect to 16 input channels with 1480nm pumping

It is clear from above table the o/p power is increased with increase in pump power. As the signal power increases, it start to compete with the clamping laser for the inverted population, diminishing the degradation caused by clamping process. However, as the signal power is continuously growing there will not be enough inverted population to keep the amplification processes, leading to larger noise figure values.Table 1.2 shows that the gain and noise figure of 16-channels simultaneously fabricated on a same fiber fort amplification with different pumping wavelength. In case of 980nm the gain flatness 38±0.5 and the noise figure is less than 9db with a maximum output power is 24.432dBm at the pump power of 500mw. While on other hand, if we use the pumping wavelength 1480nm than the gain is increase and the noise figure is reduced. In 1480nm, the gain flatness is of 40±0.5 and the noise figure is less than 6dB with a maximum output power is 24.557dBm at the pump power of 500mw.

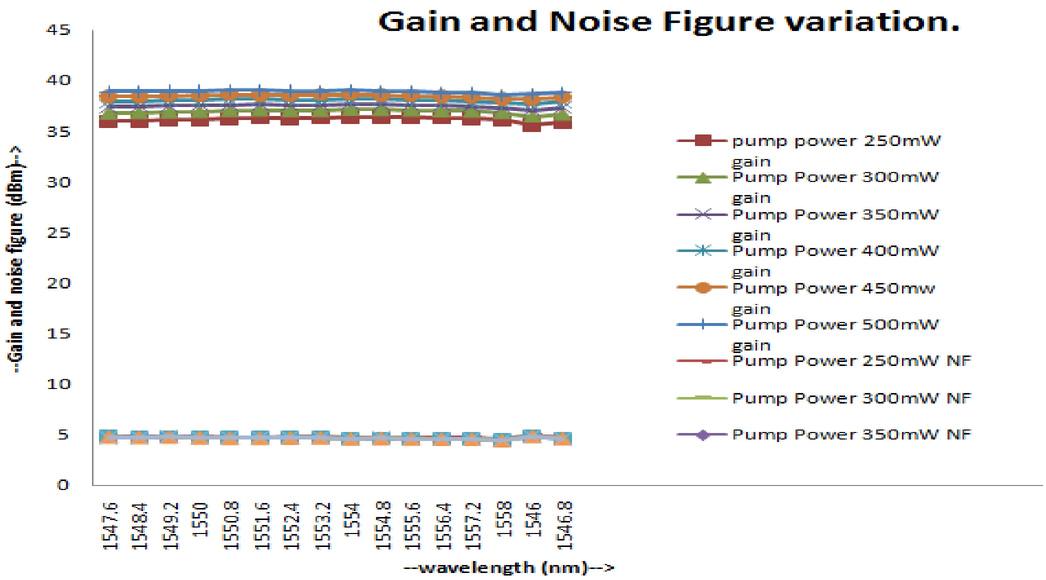

Fig. 1.4: Gain and NF variation of -26dBm/ch amplification for different pump powers

Figure1.4 shows the gain and noise figure variation of the 16-channels with a input power of -26dBm amplification for different pump power. In here we use the pumping wavelength as 1480nm instead of 980nm. Figure 1.5 shows the dependency of the output power on pump power, as we increases the pump power the output power is increases. In case of 980nm pumping wavelength the output power is less as compared to 1480nm.

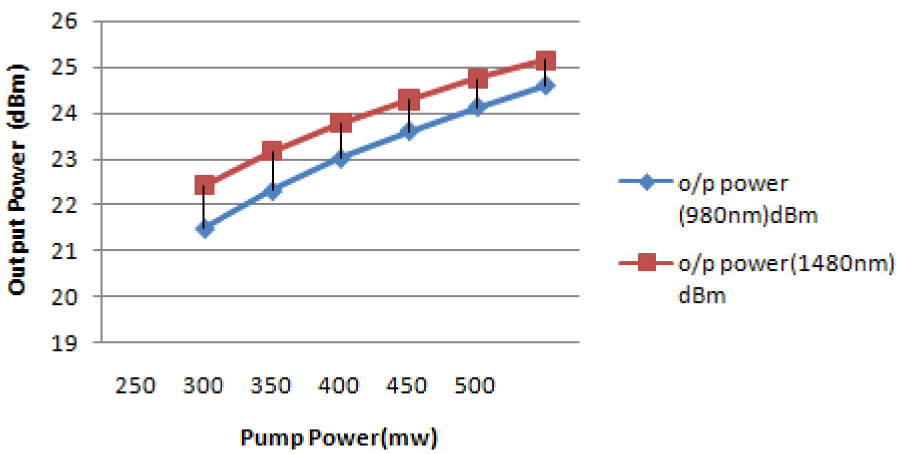

Figure 1.5: output power vs pump power with different pumping wavelength

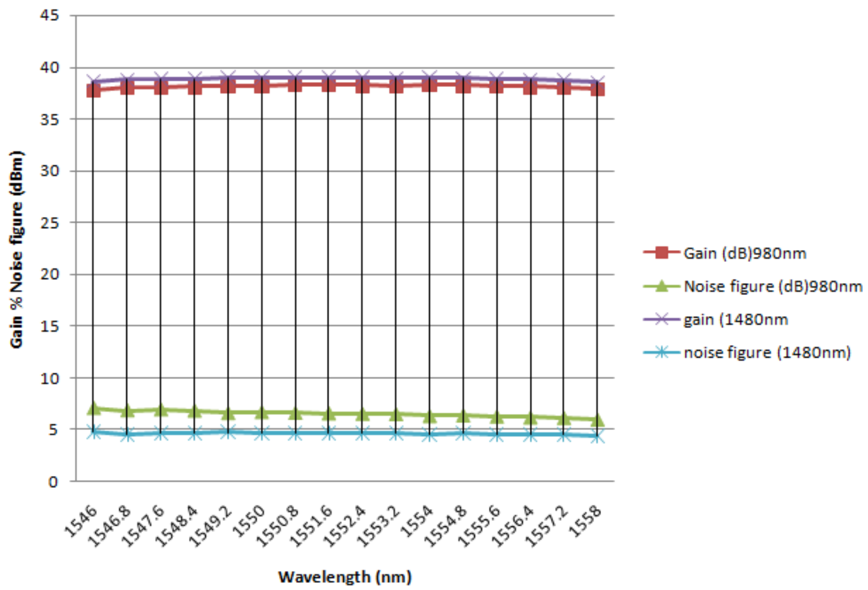

Figure 1.6: Gain and NF variation of -26dBm/ch amplification for different pump powers with different pumping wavelength

Figure 1.6 shows that the gain and noise figure of 16-channels simultaneously fabricated on a same fiber fort amplification with different pumping wavelength. In case of 980nm the gain flatness 38±0.5 and the noise figure is less than 9db with a maximum output power is 24.432dBm at the pump power of 500mw.

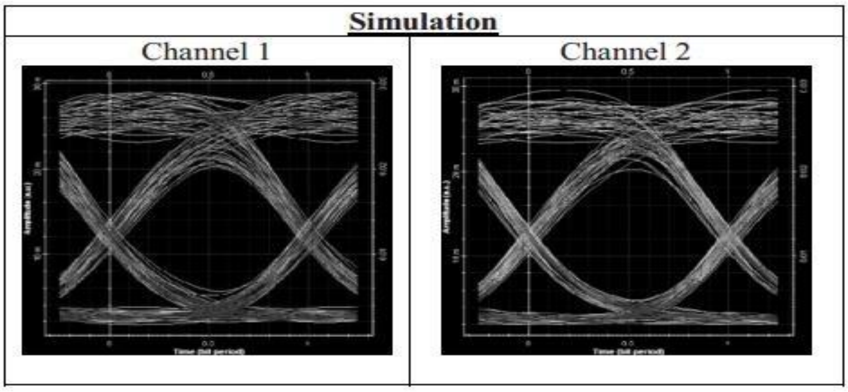

Figure 1.7: Eye diagram from channel 1 and channel 2

Figure 1.7 describes the comparison between Eye diagram from the journal and the simulation results. The Eye diagram shown here, gives us the bigger opening that refers that it has lower inter symbol interference (ISI) while the width of opening indicates the time for which sampling is perform for the purpose of detection. Here, optimal sampling time corresponds to maximum Eye opening yielding greatest protection against noise.

VI. Conclusion

In EDFA, each stage's pump power and mid-stage attenuation are controlled according to the power variation of the input signal channel channels and the optical supervisory channel, respectively. The different pump power can affect the output power base on their length of fiber. As the pump power increases, the gain flatness became worst which lead to more noise and bit-error-rate (BER). By choosing proper fiber length and injected pump power to EDFA, the population inversion can be controlled. The output power is directly proportional to pump power. Hence the increase in output power leads to increase in pump power. The optimum fiber length is 8m. The system for 16-channel's amplification is designed with the values of Gain flatness 40±0.5 within the bandwidth of 1546nm to 1558nm.the output power of the designed model is 24.557 dBm along with a average noise figure <5dB at pump power of 500mw.

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