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Gain and noise figure Characteristics of EDFA for Fiber Communication Advancement

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Abstract:

Fiber loss, interference, dispersion etc are the basic limitations in realizing long distance fiber optic communication systems. Amplification of light waves by the use of Erbium-doped fiber amplifiers (EDFAs) has become the effective solution to tolerate the limitations caused by fiber attenuation and losses. The information signal of interest in fiber optic communication system with EDFA is mainly depends on pump power, pump wavelength, Er-ion concentration, Er-doping radius, fiber length etc termed as input parameters. The performance evaluation parameters of the fiber optic communication systems are gain, noise figure, degradation, radiation tolerance, spectral burning etc termed as output parameters. We have studied the combined analysis of input and output parameters of fiber optic communication system with EDFA. The simulation results shows that Optical pumping at 980nm can achieve a wide range of bandwidth(>35nm), with a gain flatness of <0.7db also pumping at 980nm leads to larger gain variations as compared with pump configurations using 1480nm. The highest degradation was observed for the EDFA using the fiber with the lowest Er-ion concentration. Furthermore there should be an optimal Er -ion concentration, which provides the best radiation tolerance. Also by suitably adjusting the pump power can able to resolve the gain degradation at 980nm & 1480nm optical pumping. There by we can achieve enough bandwidth. The optimum value of Er-doping radius was observed as 2.0um also the gain peak shows at signal wavelength 1532nm.

Index Terms—**Erbium doped fiber amplifier (EDFA), gain, noise figure, Er-ion concentration, radiation tolerance.**

I. INTRODUCTION

Nowadays we can't imagine the world without communication. The use of fiber optic communication emerges due to its low weight, high bandwidth, easy to maintain, low cost etc. Because of its wide variety of advantages fiber optic communication system has wide range of applications also. The fiber optic communication systems are used in telephones, internet services, cable television, closed circuit television, military applications etc. Although the communication system suffers from fiber loss, attenuation, dispersion, etc [1], [2] Optical amplifiers are used to overcome these limitations occurs in fiber optic communication systems. The optical amplifiers were developed in 1980s and commercially available in 1990s. The most significant types of optical amplifiers are Raman amplifier [3], semiconductor laser amplifier, Brillouin amplifiers and rare-earth doped fiber amplifiers.

EDFA(Erbium doped fiber amplifier) is a special class of optical amplifier widely used today. EDFA has several parameters such as pump wavelength,

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pump power, signal wavelength, signal power, Er-ion density, Er-doping radius, Fiber length, Gain, Noise figure etc. Out of them the overall performance of fiber optic communication is mainly depends on the gain-noise figure values. The gain-noise figure are highly depends on the parameters like pump power, fiber length, Er-ion concentration etc. Here the low powered input signal along with high powered pump signal is fed to erbium doped fiber through an optical coupler. The pump energy is transferred to the signal by the process of stimulated emission. The pump can be used at either 980nm or 1480nm. The signal wavelength shows better gain in the range of 1530-1560nm.The pump power always greater than 10mw to obtain good gain-noise figure values. The EDFA acts like an optical repeater. It amplifies the optical signal itself without ever changing it to electricity. For long haul point-to-point fiber optic communication without significant loss of power EDFA has become the best choice. We can achieve an optical gain upto 30db, it means 1000 photons out per photon in. There should an optimum value of these parameters for better performance. The amplified optical signals are given to de-modulators for optical to electrical conversion.

II. EDFA MODE OF OPERATION

In figure1 a relatively high powered pump signal is mixed up with the information signal using a wavelength selective coupler. The WDM coupler used here couples multiple wave length without any interference effects and noise. The mixed beam light beams are passed into a section of erbium doped fiber. Erbium doped fiber are optical fibers in which Er-ions are doped in the core. The high powered light beam from the coupler excites the Er-ions in the core of the fiber. The Er-ions are excited to the higher energy level. When the photons of the information signal at a different wavelength from the pump signal, meets the excited Er-ions the Er-ions give up its energy and return back to its lower energy state [4], [5].

A significant point is that the Er-ions give up the energy in the form of additional photons which are exactly same as the phase and direction of the information signal to be amplified. There should be an isolator placed ate the output stage to prevent the back scattered light and unwanted reflections. Otherwise these reflections may disrupt amplifier operations and in the extreme case the amplifier acts like a laser. Before entering the erbium doped fiber the information signal is low powered beam and after the fiber the signal becomes stronger. Therefore the Erbium doped fiber can call it as gain provider. Within the fiber itself the information signal gets multiplied and gain increased.

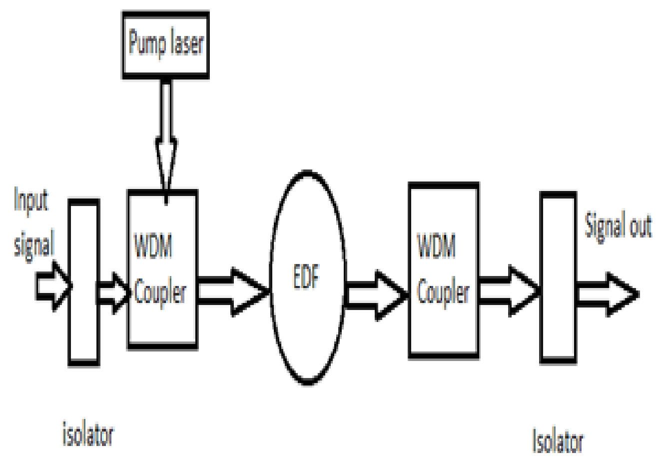

Fig1. Working model of Erbium doped fiber amplifier

III. SIMULATION MODEL

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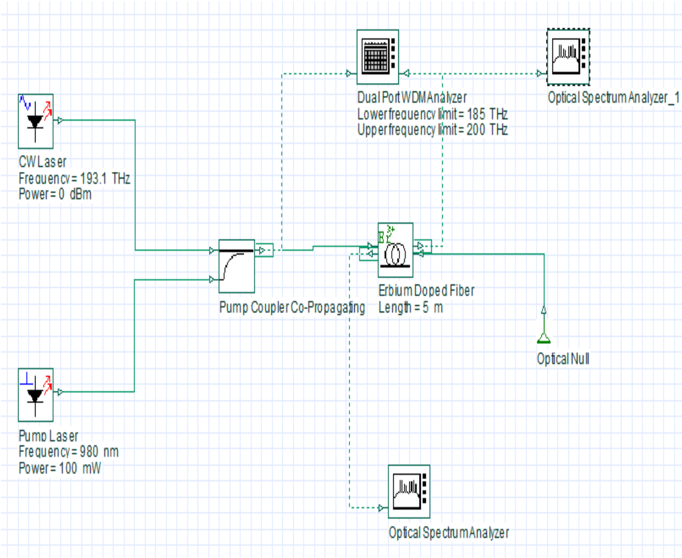

Fig3. Simulation model used for combined analysis of fiber optic communication system with EDFA in Optisystem

The simulation model in optisystem is shows in fig 3. Here the information signal and the pump signal is passed into the EDFA with sufficient Er-ion density through the coupler. The information signal is at 1552.52nm and pump signal is at 980nm . Pump power is selected at 100mw. Then simulate the output for different values of pump power, pump wavelength, signal wavelength, Er-ion density, Er-doping radius in terms of gain and noise figure. One more parameter that is strongly depends on the gain also considered, terms the fiber length. Then vary these parameters in a combined manner so that better gain, noise figure is obtained. Also the effect of radiation tolerance is further reduced.

IV. RESULTS AND DISCUSSION

A. Gain dependency on pump and signal wavelength

The dynamic response of the amplifier is obtained when switching from the red sub band channels to the blue sub band channel. Since the goal is to assess the pump wavelength dependency, the gain of the probe channel remains unchanged during the number of values. This is achieved by adjusting the pump power at different pump wavelengths to obtain the reference gain of the probe channel. Pump wavelength dependency is determined by using different pumps. In addition to several pumps with emission wavelengths in the 1480-nm range, a pump at 980 nm is also taken into consideration. In the 980nm, population of the third energy level comes into consideration, whereas a two-level model is sufficient when pumping in the 1480-nm range. For pump wavelengths around 1465 and 1480 nm, there are only small differences with respect to the magnitude of these variations, with slightly larger variations for smaller pump wavelengths.

For comparison purposes, gain variations for a 980-nm pump are also shown in table 1, 4. As compared to the configuration with 1480-nm pumping, the magnitude almost doubles. In summary, the results clearly demonstrate that the magnitude of gain variation for pumping at 980 nm is almost twice the value observed in the case of pumping in the 1480-nm range.

Pump wavelength(nm)	Gain(db)	Noise figure(db)
980	17.52	3.43
970	17.21	3.57
960	15.70	4.04
950	11.25	5.50
940	8.53	6.58
930	8.90	6.42
920	8.85	6.44
910	8.80	6.46
900	8.75	6.48
990	16.60	3.79
1000	14.90	4.29
1010	11.83	5.30
1020	8.36	6.66
1030	3.87	8.60
1040	-113.58	119.77

Table1 represents the gain variations around 980nm pumping

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Pump wavelength(nm)	Pump power(mw)	Gain(db)
980	100	17.52
970	105	17.51
960	150	17.50
950	400	17.50
940	680	17.51
930	640	17.53
920	645	17.52
910	650	17.52
900	655	17.51
990	120	17.50
1000	180	17.50
1010	355	17.51
1020	705	17.52

Table2 represents the gain flattening at 980nm optical pumping

The gain flatness at 980nm is simulated by performing the combined analysis of pump power, pump wavelength and gain. The simulation results shows that, gain flatness of <0.1db can be achieved over a wider bandwidth (> 100nm) . There by we can overcome the gain degradation problem at 980nm optical pumping.

Pump wavelength(nm)	Pump power(mw)	Gain(db)
1480	100	18.47
1470	105	18.49
1460	115	18.46
1450	140	18.47
1440	180	18.45
1430	240	18.48
1420	325	18.48
1490	105	18.46
1500	130	18.45

Table3 represents the gain flattening at 1480nm

The gain flatness at 1480nm is simulated by performing the combined analysis of pump power, pump wavelength and gain. The simulation results shows that, gain flatness of <0.1db can be achieved over a wider bandwidth (> 80nm) . There by we can overcome the gain degradation problem at 1480nm optical pumping. Compared to 980nm pumping the performance of fiber communication system can be enhanced while using 1480nm optical pumps. In 1480nm pumps the pump power requirement is lower compared to 980nm pumps as well as the optical gain is much higher (18.47db) , where as in 980nm pumps the gain obtained is 17.52db only.

Pump wavelength(nm)	Gain(db)	Noise figure(db)
1480	18.47	4.34
1470	18.35	4.18
1460	17.87	4.12
1450	17.07	4.17
1440	15.99	4.32
1430	14.80	4.56
1420	13.46	4.90
1490	18.25	4.60
1500	17.57	4.96
1510	16.18	5.45
1520	13.70	6.10
1530	9.92	7.00

Table4 represents the gain variations around 1480 nm pumping

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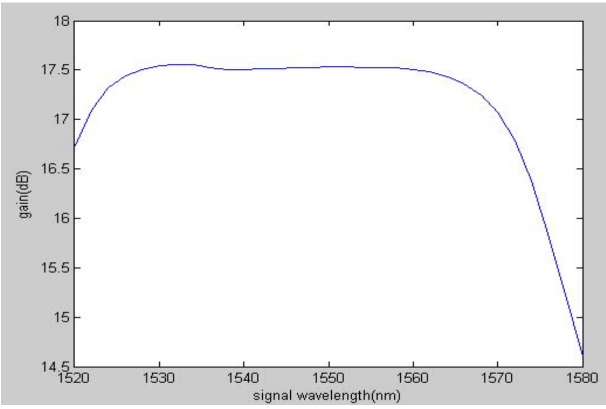

Fig 4 dependency of gain on signal wavelength

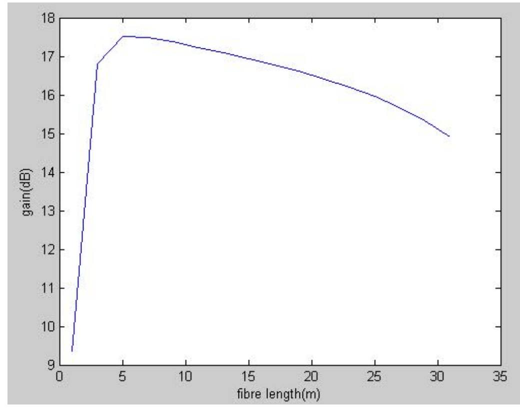

Figure 5 dependency of gain on fiber length

The above figure shows the dependency of gain on wavelength obtained from the simulation for a series of signal wavelength. From the obtained values the optimum value of signal wavelength that provides the best performance is at 1532nm. At this wavelength we can achieve a gain of 17.55db at 980nm pump wavelength, 100mw pump power and the fiber length 5m.

B. Gain dependency on Er-ion concentration

In the simulation model initially the Er-ion concentration is select at 1e+020. The strongest degradation was observed for the EDFA using the fiber with the lowest Er -ion concentration. The effect on the two other EDFAs is similar. We conclude that there is an optimal Er -concentration, which provides the best radiation tolerance.

C. Gain dependency on fiber length

The dependency of gain on fiber length analyzed. The simulation results shows in figure5. The fiber length that gives best performance is at 5m. Above and below this length the obtained gain shows a decrease in gain.

V. CONCLUSION

The dependency of the performance parameters of EDFA on pump wavelength, pump power, Er-ion concentration, Er-doping radius and fiber length has been simulated. The magnitude of gain variations with pumping at 980 nm is almost double the value observed in the case of pumping in the 1480-nm. Furthermore, almost no difference between 1465- and 1480-nm pumping has been observed. The highest degradation was observed for the EDFA using the fiber with the lowest Er -ion concentration. We conclude that there is an optimal Er -concentration, which provides the best performance. Furthermore by suitably adjusting the pump power can able to resolve the gain degradation at 980nm & 1480nm optical pumping. There by we can achieve enough bandwidth**.** The optimum value of Er-doping radius was observed as 2.0um also the gain peak shows at signal wavelength 1532nm.

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