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Comparatively analysis of Erbium Doped Fibre Amplifier for Fibre Communication

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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 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.

Keywords:- Erbium doped fiber amplifier (EDFA), gain, noise figure

I. INTRODUCTION

Optical amplifiers have been essential elements for high capacity, long-lifespan and multiple connection of optical for communication network applications, since it compensates loss through transmission of information via transmission medium, the passive components and the power division for connectivity of multiple points [1]. WDM is basically a fiber optical transmission technique, which multiplexes many signals of different wavelength and is capable of providing data capacity in excess of hundreds of gigabit per second over thousands of kilometers in a single mode fiber. At the present, most countries in the world have implemented Internet infrastructure by means of WDM systems to provide high bandwidth and a high-speed Internet service. Optical amplifiers applies in general application such as inline optical amplifiers, preamplifier and power or booster amplifier, plus devotes its crucial applications to carry information at long distances of more than 100 km, which has been an important criteria for telecommunication application. Today, most optical amplifiers have presented advanced complex systems and reduce usage of repeaters to couple one fiber cable to another in order to reduce loss in transmission, despite the earlier version introduce simpler and straightforward system. All optical amplifiers functions to increase the power level of incident light through a stimulated emission or optical power transfer process [2]. These amplifiers are widely used in WDM networks with larger channel numbers, which requires higher total pump power. The optical pumps usually are of semiconductor laser at output range of 20 – 33 dBm, in which, might expose to hazards such as eye and skin damage risks and possibility of fiber explosion in case the beam are excessive and spread through edges of fiber, thus lead to fiber fuse effect as well. The other challenge that might be faced by the optical system design is the noise generation of amplifiers, not only that; it has to deal with non-linear optical cross-talk in transmission fibers [3].

Optical amplifiers mostly help in extending power budget, thus reduces number of connectivity points. Optical amplifiers also are designed to lessen the effects of dispersion and attenuation, which allows improved performance for long-haul optical systems.

EDFA (Erbium doped fiber amplifier) is a special class of optical amplifier widely used today. EDFA has several parameters such as pump wavelength, pump power, signal wavelength, signal power, Erion 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 gainnoise 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 demodulators for optical to electrical conversion.

II. EDFA AND PUMPING REQUIREMENTS

The structure of a typical EDFA is shown in figure 1. EDFAs consist of optical couplers to combine pump and signal lights injected to active fiber, unidirectional optical isolators, pumping lasers, polarisation couplers to combine pump sources and optical bandpass filters to reduce out of band noise. The gain characteristics of EDFAs depend mainly on their pumping schemes. EDFAs can be pumped at 980 nm or 1480 nm, and with different configurations: backward, forward or bi-directional. The pumping at 980 nm provides lower noise figure than pumping at 1480 nm. Therefore preamplifier version of EDFA chooses 980 nm for pumping wavelength. On the other hand, 1480 nm pumping has higher quantum efficiency and so provides higher output power at a lower cost and therefore it is preferred for booster amplifier operations. In forward pumping, both of the signal and pump lights propagate in the same direction through the fiber whereas in the backward pumping they propagate in the opposite direction. The forward pumping direction provides the lowest noise figure. In fact, the noise is sensitive to the gain and the gain is the highest when the input power is the lowest. Backward pumping provides the highest saturated output power [2]. Bi-directional pumping scheme has a higher performance than the other two by combining the lowest noise figure and the highest output power advantageous although it requires two pump lasers. In addition, in this scheme the small signal gain is uniformly distributed along the whole active fiber.

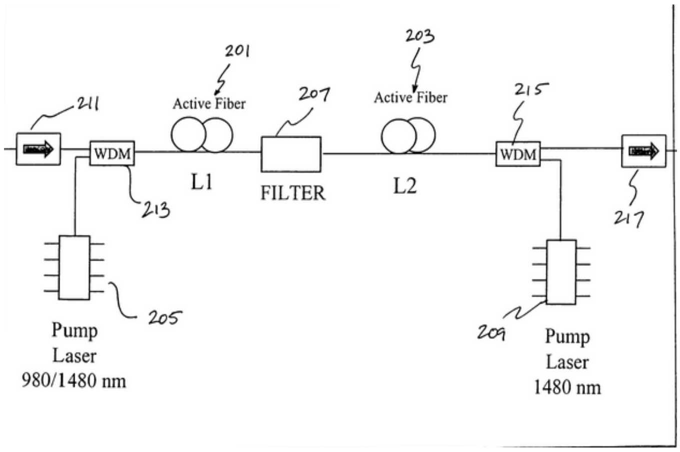

Figure 1: A bidirectionally pumped EDFA structure

III. EDFA AND PUMPING REQUIREMENTS

In pumping at 980 nm, it is required to form a system model with three energy levels. When the excited state absorption (ESA) is considered, a forth level should also be included. If the pumping is performed at 1480 nm, a simple system model with two energy levels can be used. In figure 2, erbium ion transitions of an EDFA pumped at 1552 nm was given. From figure 2, time dependent population rates in level 2 and 1 can be given as:

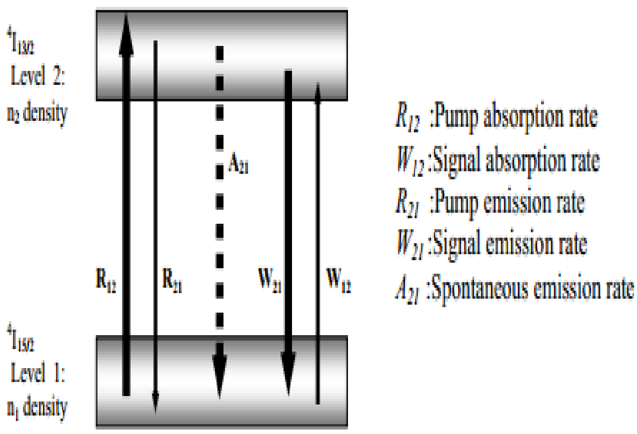

Figure 2: Erbium ion levels

$$\frac{dn_2}{dt} = +(R_{12} + W_{12})n_1 - (R_{21} + W_{21} + A_{21})n_2 \frac{dn_1}{dt} \quad (1)$$

In steady state,

$$\frac{dn_2}{dt} = 0$$

The ratio of level 1 and level 2 populations to the total population can be written as:

$$\frac{n_1}{n_t} = \frac{(R_{21} + W_{21} + A_{21})}{(R_{21} + R_{12} + W_{21} + W_{12} + A_{21})} \quad (2)$$

$$\frac{n_2}{n_t} = \frac{(R_{12} + W_{12})}{(R_{21} + R_{12} + W_{21} + W_{12} + A_{21})} \quad (3)$$

Gain of an erbium-doped fiber with a length of L is the ratio of the signal power at the fiber output to the signal power injected at the fiber input as:

$$G = \frac{P_s(L)}{P_s(0)} \quad (4)$$

ASE noise generated during amplification process is added to the signal leading to decrease in signal to noise ratio (SNR) at the amplifier output. SNR reduction ratio from input to output of the amplifier is defined as Noise Figure (NF), which is also used for electronic amplifiers:

$$NF = \frac{(SNR)_{in}}{(SNR)_{out}} \quad (5)$$

IV. OPTISYSTEM

You can enter arithmetical expressions for parameters and create global parameters that can be shared between components and subsystems using standard VB Script language. The script language can also manipulate and control OptiSystem, including calculations, layout creation and post-processing when using the script page. For any given system topology and component specification scenario, a full OptiSystem project can be encrypted and exported to Outperformer. Outperformer users can then vary any parameter within defined specification ranges, and observe resulting system effects via detailed graphics and reports.

The most efficient way to become familiar with OptiSystem is to complete the lessons in the Tutorials, where you learn how to use the software by solving problems.

V. PUMP POWER VARIATION

The attenuation of variable pump powers applied to the input of erbium doped fiber for fix length of fiber, a constant erbium doping density and signal input power. As it can be seen from figure 2, the pump power rapidly attenuates with fiber length which results mainly from two mechanisms namely erbium absorption and background loss of silica fiber. The fiber background loss, which is less effective in a short distance, causes much higher pump power depletion in a longer fiber. Due to excessive pump depletion in longer distances, the gain obtained from an amplifier begins to decrease after a maximum level.

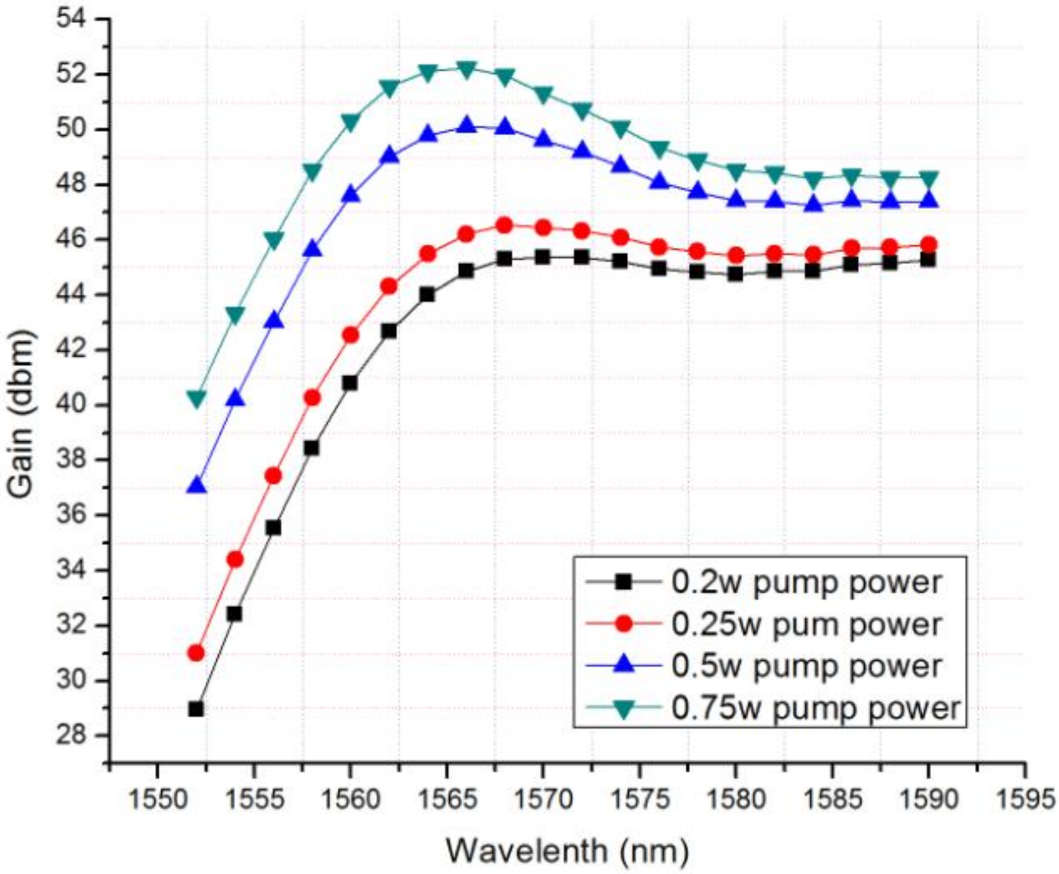

Figure 3: The Variation of Fiber Length with Constant Pump Power

VI. CONCLUSION

From the Optisystem results, it is concluded that length-5 fiber is the most suitable fiber for the four-stage implementation of EDFA. The same EDFA has been implemented in Optisystem with further customizable parameters. The pump power was variable, Pump Powers like 0.75were used. Analyzing the gain and noise figure spectrum for the EDFA under different pump powers, it was concluded that the pump power of 0.75 W gives better results.

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