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RESEARCH ARTICLE

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PERFORMANCE ANALYSIS OF EDFA AMPLIFIER IN C-BAND AND L-BAND FOR WAVELENGTH DIVISION MULTIPLEXED PASSIVE OPTICAL NETWORK

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ABSTRACT

The biggest concern in our next generation wavelength division multiplexing (WDM)/ Time Division Multiplexing (TDM) Passive optical network (PON) is the propagation loses. Erbium Doped Fiber Amplifier (EDFA) has greatly helped in overcoming the propagation loses. So this paper analyzes the performance characteristics of EDFA for different pump powers and wavelengths. The optisystem software is used to obtain the curves in terms of bit error rate (BER), Noise figure and Gain in a WDM PON. The Pump wavelengths used are 980nm and 1480nm where as pump power ranges from 10mW to 1W.

Keywords- Passive optical networks (PON's), Erbium Doped Fiber Amplifier (EDFA) Wavelength division multiplexing (WDM), Time division multiplexing (TDM), Bit error rate (BER), Noise figure (NF), central office(CO), Optical Line Terminal (OLT), Remote Node (RN), Optical Network Unit (ONU).

I. INTRODUCTION

In recent years Fiber to the home has proved to be a potential solution for ever increasing demand of data bandwidth, security and scalability by end subscribers [1]. Commonly used cost effective FTTH systems are Passive optical networks (PONs) [2]. Passive optical networks are cost efficient because of absence of active components [3]. The major components in a PONs are optical line terminal (OLT), central office (CO), remote node (RE) and optical network unit (ONU). Passive Optical Networks with Wavelength Division Multiplexing (WDM) technology (such as WDM PON) is widely used by many internet service providers [4]. WDM PON has many advantages over traditional TDM PON like bandwidth, transparency in protocol, quality of service (QoS) and lesser channel splitting losses etc. but WDM technology is more costly than TDM. One way to reduce the cost is to introduce the concept of LR-PON (Long Reach Passive Optical Network) which uses optical amplifier to increase the coverage range. Various optical amplifiers are available such as Semiconductor optical amplifier and fiber amplifiers. The EDFA is used widely because its emission coincides with the 1.55 µm window [5] in conventional single-mode fibers (SMF) [6]. EDFA is a conventional silica fiber heavily doped with active erbium ions as the gain medium. EDFA can operate in the 1500nm-1600nm wavelength range simultaneously [7]. As 1500-1600nm wavelength range include both C and L band EDFA contribute a lot in wavelength division multiplexing for amplification. The amplifying medium is nothing more than a piece of normal optical fiber that is doped with the rare earth element erbium (Er) during fabrication. The rest of the paper is organized as follows. In section II we explain the operating principle of EDFA. In section III the simulation setup is discussed along with the block diagram. Performance of EDFA is analyzed using different parameters. In section IV simulation results are obtained in terms of Gain, Noise figure and BER. Conclusions drawn from the obtained results are given in section V.

II. ERBIUM DOPED FIBER AMPLIFIER

The EDFA on a quantum level is sufficiently described by a three level system. The electrons of erbium fiber can be excited to higher energy levels by pumping with shorter wavelength light. Pump wavelengths of 980nm and 1480nm are mostly used to excite erbium's quantum levels as this will not lead to great losses in the optical fiber. A two-level system approximation is used in this model. Under the assumption of the normalized population densities N_1 and N_2 at the ground and meta stable energy level, $^4I_{\frac{15}{2}}$ and $^4I_{\frac{13}{2}}$ populations are calculated by numerically solving the rate and propagation equations.

$\frac{\partial N_2(z,t)}{\partial t} = -\frac{N_2(z,t)}{\tau} - \frac{1}{A_{eff}}\sum_{n=1}^{N}\{\Gamma_n[(\sigma_n^e +$

σnaN2z,t−σna[Pn+z,t+Pn−z,t] (1)

s $N_2 + N_1 = 1$

$\frac{\partial P_n^{\pm}(z,t)}{\partial z} = u_n\{\rho\,\Gamma_n[(\sigma_n^e + \sigma_n^a)N_2(z,t) - \sigma_n^a -$

αPn±z,t+2ρΔvN2Γnσne (2)

where the optical powers are expressed in units of number of photons per unit time, τ is the metastable spontaneous emission lifetime, N is the number of channels taken into account in the simulation, ρ is the number density of the active erbium ions, is the attenuation coefficient (which takes into account the background loss of the fiber), Δv is the frequency step used in the simulation to resolve the amplified spontaneous emission spectrum, and A_{eff} is the effective doped area given by , $\pi \times b^2$ where b is the Er doping radius (it is considered a uniform distribution of erbium ions in the area given by the Er doping radius region). The nth channel of wavelength λ_n has optical power $P_n(z,t)$ at location z and time t, with emission and absorption cross-section σ_n^e and σ_n^a respectively, and confinement factor Γ_n . The superscript symbols + and − are used to indicate channels traveling in forward (from 0 to L) and backward (from L to 0) directions, respectively. For beams traveling in the forward direction $u_n = 1$ and for beams in the opposite direction $u_n = -1$.

III SIMULATION SETUP

Figure1 illustrates a schematic diagram of the downstream WDM PON system based on EDFA.

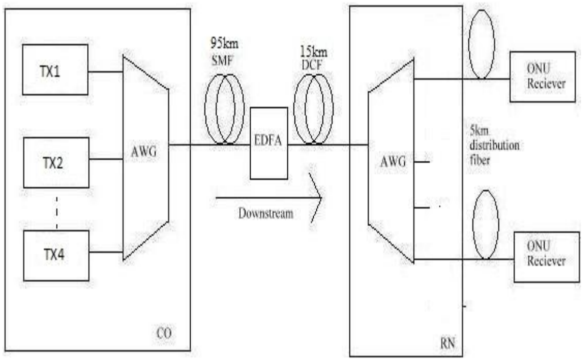

Figure 1: Block Diagram of Simulation Setup

At the central office (CO) 16 channels are multiplexed with a channel spacing of 100GHz covering both C-band and L-band with a channel spacing of 100GHz using continuous wave lasers. NRZ modulation is used because NRZ data modulation format is most suitable format for passive optical network (PON) [8]. NRZ modulation signal modulates the continuous wave lasers using Mach-Zehnder modulator at 10 GB/s and PRBS $(2^{31} - 1)$. For multiplexing and demultiplexing we used arrayed waveguide grating (AWG). The multiplexed signal is passed through a fiber span of 115km. The fiber span of 115km consists of 100km of single mode fiber (SMF) and 15km of dispersion compensation fiber and an Erbium Doped Fiber Amplifier (EDFA). The amplified signal is then demultiplexed at the RN into sixteen transmitted wavelengths and. This demultiplexed signal passes through a 5km SMF before reaching the optical network unit (ONU) [9].

At the receiver end each ONU section consists of a variable attenuator, PIN photodiode, a low pass filter (LPF), filter regenerator and a analyzer as shown in figure 2. Received optical signal is converted into electrical signal using PIN photodiode [10] and LPF reduces the noise by filtering the high frequency signal.

IV SIMULATION PARAMETERS AND DISCUSSION

Simulation parameters used are summarized in the table below

Table 1. Parameter values

PARAMETER	VALUE
CW Laser Power	0dB
AWG Loss	6.6dB
EDFA length	2.4m
SMF loss	0.2dB/Km
DCF loss	0.5dB/Km

To investigate the performance of EDFA in WDM PON architecture we measure the Gain and Noise figure of EDFA using Dual Port WDM analyzer and BER values using BER analyzer. BER values lower than 10^{-9} are considered error free operations. A plot between Bit Error Rate (BER) and Pump Power are drawn as shown in fig2 for 4 channels which clearly shows that Log of BER values increases with increase in pump power values but at higher values Log of BER values becomes constant.

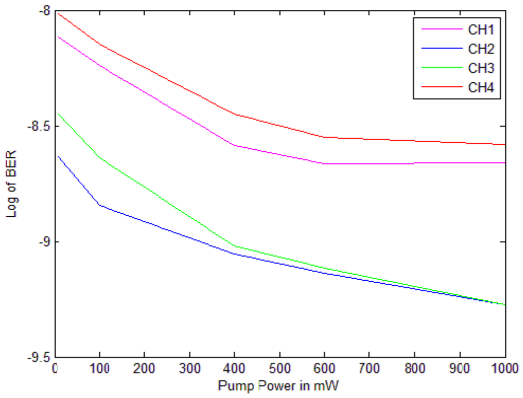

Figure2. BER vs Pump Power

Figure3. shows the measured signal gain values for both c-band and L-band. The measured signal gain has an average value of 24dB for both 980nm and 1480nm pump wavelength. The gain is more at 1480 nm pump wavelength as compared to 980nm.

Where as noise figure is found to be less in case of 980 nm pump wavelength in comparison to 1480nm wavelength as shown in figure 4.

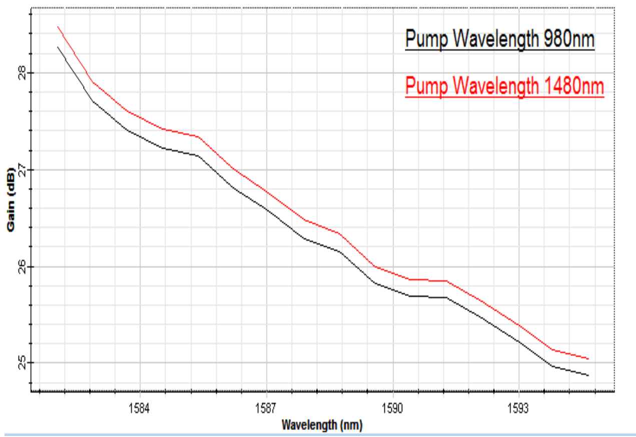

Figure3. Gain vs Wavelength

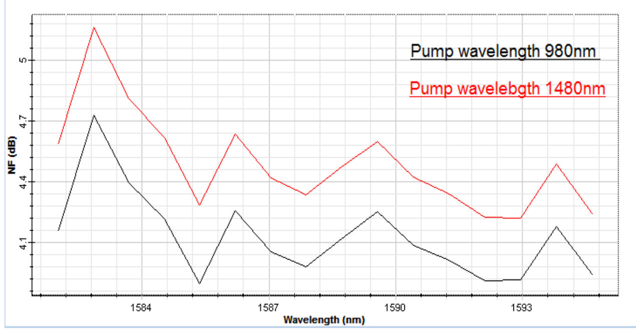

Figure4. Noise figure vs Wavelength

V. CONCLUSIONS

We have successfully investigated the performance of EDFA for different Pump Powers, pump wavelengths (i.e. 980nm and 1480nm). The investigation clearly shows that better BER values are achieved with the increase in pump power but BER becomes almost constant after reaching a max limit. Also noise figures values and gain values are observed for pump wavelength of 980nm and 1480nm. Pump wavelength of 1480nm provide higher gain values in comparison to 980nm pump wavelength where as noise figure value also increases for 1480nm pump wavelength. The results shows that 980nm pump wavelength provide better noise figure values but has lesser gain values in comparison to 1480nm.

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