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Study of Erbium Doped Fiber Amplifier

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ABSTRACT

Optical fiber amplifier is key enabling technology used for high speed optical communication. One of the Amplifiers is Erbium Doped Fiber Amplifier, Which is modeled using the propagation and two level or three level rate equations. The performance of amplifier is depends on various parameters like, Er^{3+} concentration, fiber length, pump and Signal Power etc. The discussion presented in this article is based on the Study analysis of EDFA for its suitability as an optical amplifier.
Keywords: EDFA, EDF, ESA, ASE, Giles Model, Saleh-jopson Model.

I. INTRODUCTION

Today, most of the optical fiber communication system use EDFAs, due to their advantages in terms of bandwidth, high power output, and noise characteristics. Erbium doped fiber amplifier is a optical amplifier, it amplifies weak input optical signals directly without any conversions pumped with a laser diode [1]. The main application of EDFA is to amplify signals in optical domain. The EDFA became a key enabling technology for optical communication networks, and have since comprised the vast majority of all optical amplifiers deployed in the field [7]. It is a most stable optical amplifier with operating bands 1550 – 1565 nm wavelength region. It works best in this range with gain up to 30-40.

II. Modeling of EDFA

The method of developing EDFA uses different modeling techniques. The Giles model solves the steady state rate equation utilizing gain and absorption parameters which are proportional to the cross sections [2]. This model includes propagation equation, which allows modeling along the length of the fiber. Saleh-Jopson model provide analytical solutions to the propagation equation. The higher erbium concentration model include the inhomogeneous effects such as ion-ion interaction and ESA. Absorption and emission cross section are essential parameter to know for any types of EDFA modeling [2].

1. GILES Model

The simpler method of erbium doped fiber can be characterized by using amplifier equation in terms of the erbium absorption coefficient α(λ), gain coefficient (λ), a fiber saturation parameter and excess loss in the fiber from scattering and impurity absorption *l*(λ).These easily measured parameters allow the fiber performance evaluation in 980 nm or 1480 nm pumped optical amplifiers. Conventional fiber measurement techniques are used to obtain these parameters, from which the amplifier performance can be calculated.

The rate equations for forward (+) and backward (-) propagating beams are

$$\pm\frac{dp_k}{dz} = (\alpha_k + g_k^*)\frac{\eta_2}{\eta_1}p_k^{\pm} + 2g_k^*\frac{\eta_2}{\eta_1}hv_k\Delta_k - (\alpha_k + l_k)$$

$$\frac{\eta_2}{\eta_1} = \frac{\sum_k \frac{p_k}{hv_k}}{1 + \sum_k p_k^{\pm}(\alpha_k + g_k^*)/hv_k\zeta}$$

Where, $\alpha(\lambda) = \sigma_a(\lambda)\Gamma(\lambda)N$

$$g^*(\lambda) = \sigma_e(\lambda)\Gamma(\lambda)N$$

$$\zeta = A_{eff}N/\tau$$

2. Saleh –Jopson Model

This model developed for estimation of the pump and signal power along the length of the EDF fiber. The Saleh-Jopson model valid for amplifiers with gain less than 20 dB, and gain saturation by ASE can be neglected [2].

The pump signal absorption and signal gain in EDF can be obtained by solving transcendental equation. When the pump and signal power propagate through fibber the change in power in the k^{th} beam can be obtained. by,

$$\frac{dp_k(z,t)}{dz} = N\mu_k\Gamma_k((\sigma_k^e + \sigma_k^a)N_2(z,t) - \sigma_k^a)p_k(z,t)$$

$$p_k^{out} = p_k^{in}\exp(-N\Gamma_k\sigma_k^a L)\exp(\frac{A(p_{in}-p_{out})}{\Gamma_k(\sigma_k^e + \sigma_k^a)\tau})$$

Where, p_k^{in} and p_k^{out} are total input and output power [2].

III. EDFA Characteristics

Overlap Factor of Amplifier

Let us consider 1-D model of the fiber amplifier, the overlap factor is known as overlap between transverse intensity profile of optical mode and transverse erbium ion distribution profile. This overlap will stimulate absorption or emission from the transitions.

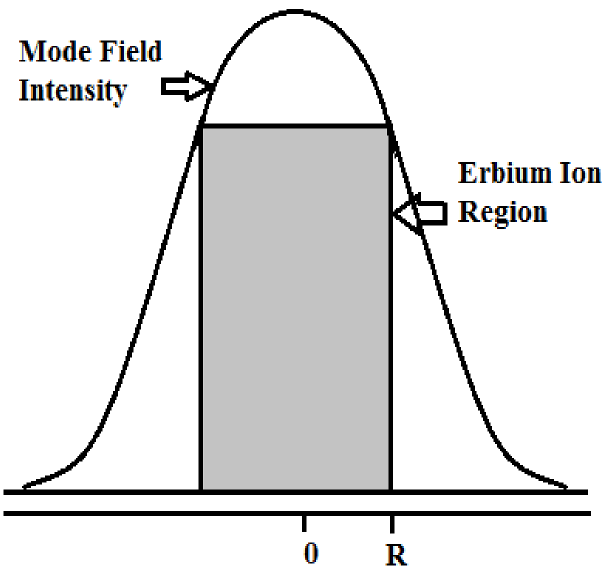

Figure 1. Overlap between erbium ion distribution and transverse intensity profile

Optimum Length of EDF

The input signal is amplified along the length of the EDF at fixed pump power up to a particular point, after that point the gain is -ve, and so the fiber should be terminated at the point [3]. At this point the pump power is decreased to the threshold level. The length of the fiber at that specific point is determined optimum length of EDF for EDFA. The optimum length at maximum gain is shown in Figure 2. Linear effects caused the majority losses of optical transmission signal through optical fibers. These linear effects are dispersion and optical signal loss calles attenuation. The attenuation represents transmission loss, which means the decreasing level of signal power with increasing length [3].

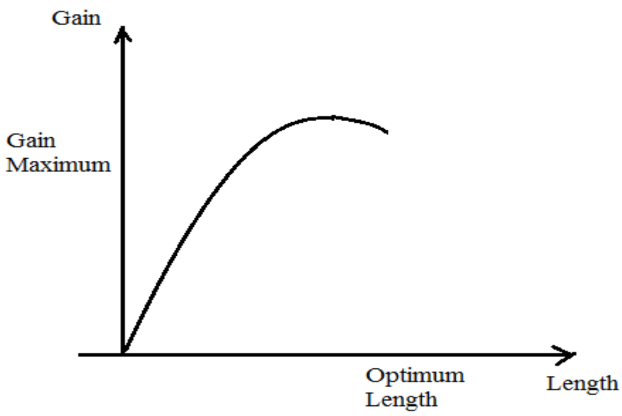

Figure 2. Optimum length at maximum gain

Amplified Spontaneous Emission

It is a sponging process, which can occur at any frequency within the fluorescence range of the amplifier transitions. The effect of ASE is to reduce the total amount of gain available from the amplifier [4]. EDFA would introduce ASE noise and thus the channel optical SNR degrades with the addition of EDFA in optical link [4].

The excited ions can spontaneously relax from the upper state to ground state by emitting a photon that is uncorrelated with the signal photons. The spontaneously emitted signal is amplified, it travels along the fiber. It stimulates the emission of more photons from excited state as shown in Figure 3. This process is known as ASE. The ASE power sometimes referred to as an equivalent noise power. The ASE power is in watts, and refer to the wavelength deviation of ASE power around is Plank's constant [5].

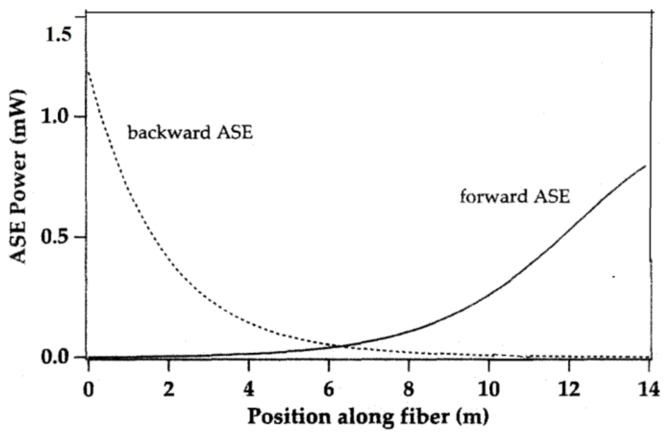

Figure 3. Amplified Spontaneous Emission [6]

The total ASE power at a point z along the fiber is the sum of the ASE power from the previous sections of the fiber and added local noise power. This local noise power will stimulate the emission of photons from excited erbium ions [6].

IV. CONCLUSION

The discussion presented in this article is based on the simulation analysis of EDFA for its suitability as an optical amplifier. As we know, the optical fiber systems are important in telecommunication for world-wide broadband network. Large bandwidth signal with low delay and attenuation is key requirement in the present day application. The optical fiber communication industry is an evolving one; the growth experienced by the industry has been enormous in this past decade.

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