International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 02, February-2018

Analyzing Gain Spectrum and ASE (Amplified Spontaneous Emission) of EDFA (Erbium Doped Fiber Amplifier) by using Matlab

Padavala Alekhya [1]
Komaravalli Byula Grace [2]
Narisetty Sukshitha [3]
Loka Jyothirmai[4]
B.Tech, Electronics and Communication,
Vasireddy Venkatadri Institute of Technology,
Andhra Pradesh, India

Abstract: **- The scope of this paper is to analyze the performance is augmented gain EDFA systems using single and multi-wavelength input sources. The performance of an Optical Communication System can be improved by the use of EDFA as an Optical Amplifier. Erbium Doped Fiber Amplifier (EDFA) is an important element in DWDM networks. A significant MATLAB code is developed, which provides the ability to handle multiple channels, thereby allowing to observe the EDFA gain versus wavelength. Since the gain is non-uniform, it is important to know its characteristics in WDM applications where many channels are sent through amplifier. Addition to this includes the forward Amplified Spontaneous Emission (ASE). The resulting model is practical and accurately represents EDFA gain dynamics and forward ASE.**

Keywords: - EDFA System, Optical Communication, MATLAB, Amplified Spontaneous Emission (ASE), Augmented.

I. INTRODUCTION

Optical amplifiers are interesting because they provide a method by which long distance communication over optical fiber can be done. Nevertheless, when signal travelling over long distances, it attenuates. So, an optical amplifier is used to reconstruct the signal. This protects the transmitted signal characteristics. One of the most popularly used amplifiers for military telecommunication applications are erbium doped fiber amplifier. There are most commonly used since they contributes optical amplification when compared to other electrical amplifiers. Electrical amplifiers performs good for moderate speed signal wavelength operation, where as optical amplifiers works well for multi wavelength operation.

EDFA's are extensively used in wavelength division multiplexed systems because electrical amplification is complex and pricey for multi-wavelength systems. But, there is a problem with using EDFA's in multiplexing systems because the gain of the EDFA is not uniform over the entire 1550 nm window (i.e. 1530 nm – 1560 nm). Distinct wavelength signals experience distinct gains and therefore experience a distinct signal to noise ratio. It is crucial to compensate for this non-uniform gain spectrum.

The software programs provide simulation for EDFA models that are mostly static. Therefore, the MATLAB code is developed, provides the capability to modify the input signal power and more significantly the input pump power of dynamic EDFA model.

II. OVERVEIW OF EDFA EQUATIONS

The dynamic EDFA model can be expressed in non linear differential equation as shown:

$$\frac{\partial}{\partial t} N_2 = P_s(0,t)[1 - e^{B_s N_2 - C_s}]$$

$$+P_p(0,t)[1 - e^{B_p N_2 - C_p}] - N_2/\tau \quad (1)$$

Equation (1) is the important equation for knowing gain dynamics in an EDFA. The co-directional input pump power is P_P (0,t) and the input signal power is P_S (0,t). Corresponding input powers are in photons/second and are related to the power in Watts by $P_{P,S}$=$P_{P,S}$ (h,υ), where υ is frequency in Hertz and h is Plank's constant in Units of J/Hz. As per our requirement we are considering the wavelength, the equation is rewritten as $P_{P,S}$ =$P_{P,S}$ $\frac{hc}{\lambda}$, where c is the speed of light in m/s and $\boldsymbol{\lambda}$ is the wavelength in m. The output pump and signal powers are

$$P_p(L,t) = P_P(0,t)\, e^{B_p N_2 - C_p}$$

$$P_s(L,t) = P_S(0,t)\, e^{B_s N_2 - C_s} \qquad (2)$$

In equation (2), quantities B and C characterize the physical EDFA and are given by

$$[B_p, B_s] = \frac{\alpha+\beta}{4.3429\rho A}$$

$$[C_p, C_s] = \frac{\alpha L}{4.3429} \qquad (3)$$

Actually the gain produced by the EDFA model is in base e, hence it is multiplied by 4.3429 to convert it to decibels.

III. HANDLING MULTIPLE WAVELENGTHS

Many signal wavelengths are handled by allowing B_S and C_S in equation (3), as well as the input signal, to be multidimensional. The input signal is wavelength dependent as shown by the formula $P_{P,S}$ = $P_{P,S}$ $\frac{hc}{\lambda}$. Hence, for each wavelength we can calculate input pump power. Furthermore, the parameters that determines the wavelength dependency of B_S and C_S are α and β, the emission and absorption cross-section coefficients, respectively.

EDFA's place an significant role in the optical communications since they have been used for multiple wavelengths. The wavelengths mainly depends upon the information of emission and absorption spectra. This helps to represent gain versus wavelength

IV. GAIN FLATTENING

A different approach gain flattening is considered in this paper. Usually the gain is flattened using a notch filter or a fiber Bragg grating, however in this paper considered how gain flattening can be done using the pump signal only. If the gain can be flattened by varying the pump signal (according to a certain relationship), then there is no need for external filters.

A relationship between the pump gain and the signal gain can be derived using equations (2) and (3) as follows.

$$N_2 = C_p / B_p + \ln(P_p(L,t)/P_p(0,t)), \qquad (4)$$

$$\ln(P_p(L,t)/P_p(0,t)) = B_s N_2 - C_s \qquad (5)$$

substitute equation 4 into 5

$$\ln\left(\frac{\text{Pp(L,t)}}{\text{Pp(0,t)}}\right) = \left(\ln(\text{Gs}) + \text{Cs} - \frac{\text{BsCp}}{\text{Bp}}\right)\left(\frac{\text{Bp}}{\text{Bs}}\right)$$

Therefore, the final equation relating the pump gain to the signal gain can be represented as follows.

$$\ln(\text{Gp}) = \left(\ln(\text{Gs}) + \text{Cs} - \frac{\text{BsCp}}{\text{Bp}}\right)\left(\frac{\text{Bp}}{\text{Bs}}\right) \qquad (6)$$

In equation (6), the signal gain ($G_{S)}$ is chosen to be 30dB, B_P & C_P are constant, and B_S & C_S vary with wavelength. The equation is plotted versus wavelength is shown. The pump gain is negative because the pumps energy gets transferred to the signal resulting in the amplification. This figure shows how the pump gain should vary over wavelength in order to achieve a flat signal gain.

Comparing it is clear that the location of the large peak (around 1530 nm) is where the pump gain should be slightly larger than for the rest of the wavelengths.

In a practical sense it might be difficult to obtain a different pump for many different wavelengths so this approach to gain flattening is something to be further researched.

V.AMPLIFIED SPONTANEOUS EMISSION

The forward ASE power is given by

$$P_{ASE} = 2n_{SP}h\upsilon\Delta\upsilon(G-1) \qquad (7)$$

$$\text{Where, nsp} = \frac{1}{1-\frac{\beta p\alpha s}{\alpha p\beta s\beta}} \qquad (8)$$

The ASE power is in Watts, G is the gain, Δυ and υ refer to the wavelength deviation of the ASE power around **λ**, h is Plank's constant, and *nsp* is the population-inversion factor which is dimensionless. In an EDFA, complete inversion can only be obtained when being pumped at 980 nm $\beta_P = 0$ and therefore nsp = 1.

It is clear that the ASE power builds up as the length of the fiber increases. This is an expected result because as spontaneously emitted photons travel down the fiber they get amplified and they also stimulate the emission of more photons. It is observed that the ASE power is relatively small at length around 4m. In this case the optimum length is chosen to be 4m compared to the 12m. However, at 4m the EDFA gain is reduced as shown. Essentially, this is one of the compromises that has to be considered when making a selection of amplifier length.

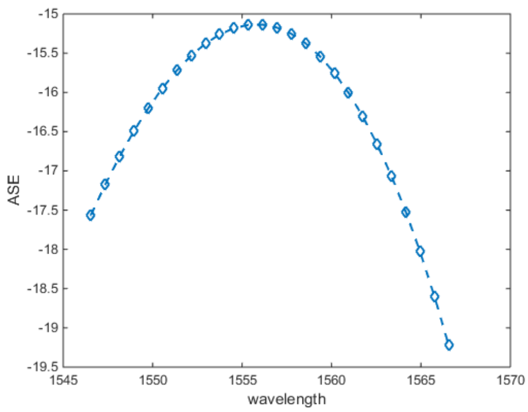
The output spectrum of the ASE is shown for a signal wavelength of 1530 nm.

The ASE spectrum is very similar to that of the gain spectrum. This is expected because of the relationship of the relationship in equation (7). Also, the ASE is present over the whole operational range of the EDFA, thereby reducing the overall gain of the system. In the EDFA usable range of 1530 nm ≤ λ_S ≤ 1560 nm, the ASE spectrum varies from -5.95 dBm to -14.7 dBm. It is clear that ASE is a dominant noise generated in the amplifier.

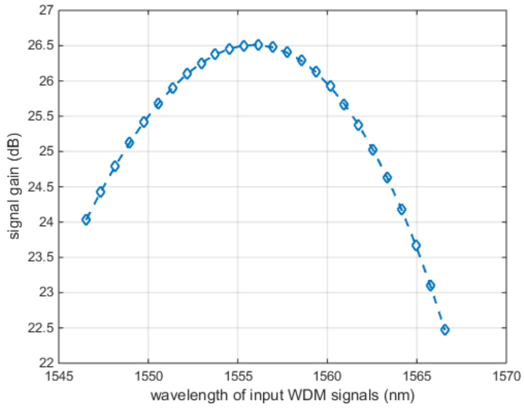
VI. RESULT

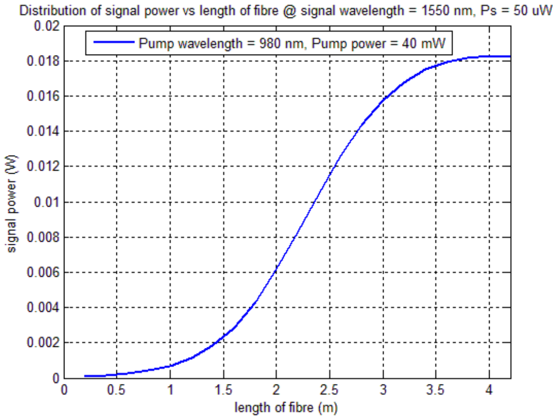
ASE power versus wavelength for λ_S of 1530 nm and λ_P of 980 nm for 4m amplifier length.

Gain versus wavelength for 12m amplifier length at λ_P = 980 nm, pump power is 18dBm and signal power is 30 dBm.



International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 02, February-2018





VII. REFERENCES

[1] P.C. Becker, N.A. Olsson, and J.R. Simpson, Erbium Doped Fiber Amplifiers Fundamentals and Technology. San Diego: Academic Press, 1999.

[2] Ö. Mermer, Ege University, "EDFA Gain flattening By Using Optical Fiber Grating Techniques," October 2001, http://bornova.ege.edu.ir/~wwweee/docs/seminer.pdf

[3] G.Keiser, Optical Fiber Communincations, [Third Edition]. New York: McGraw-Hill, 2000, pp. 423-447.

[4] X. Fernando, Ryerson University, "EE8114 fall 2003: Suggested Project Titles", September 2003, http://www.ee.ryerson.ca/%7Ecourses/ee8114/Projects/project_outline.htm

[5] S. Novak and R. Gieske, "Simulink Model for EDFA Dynamics Applied To Gain Modulation," Journal of Lightwave Technology, vol. 20, No.6, pp.986-992, June 2002.