Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2,Issue 4, April -2015

BASIC ANALYSIS OF GAIN IN TERMS OF NOISE FIGURE

[1]RAHUL SINGH CHAUHAN,[2]S,SUGUMARAN

[1]M.Tech,[2] Faculty,GALGOTIAS UNIVERSITY,GREATERNOIDA

Abstract: *One attractive fiber-optic amplifier (FDA) in optical communications systems, and particularly in DWDM systems, is the EDFA. The EDFA is a fiber segment a few meters long heavily doped with the rare earth element erbium (and also co-doped with Al and Ge). The erbium ions may be excited by a number of optical frequencies-514, 532, 667, 800, 980, and 1480 nm. The shortest wavelength, 514 nm, excites erbium ions to the highest possible energy level. From this level, it may drop to one of four intermediate metastable levels, radiating phonons (the acoustical quantum equivalent of photons). From the lowest metastable level, it finally drops to the initial (ground) level, emitting photons around 1550 nm in wavelength.*

In this paper, here we are analysing the basic effect of EDFA switching on optical amplifier gain and noise figure. A variable gain erbium-doped fiber amplifier (EDFA) with a wide gain range and a small noise figure (NF) variation is analyzed numerically and performed on MATLAB.

Keywords: *EDFA, Noise Figure (NF), Pump Power, Optical Fiber.*

I. INTRODUCTION

Future high-speed, high capacity optical communication systems will have to handle two particular types of user services: multimedia services to multiple users, and select-cast data transport from user-to-user or from region-to- region. A dynamic reconfigurable multi-wavelength channel add/drop function at the user nodes can efficiently process the information of these two types of services, with minimum electronics at the access node, at lower system cost . Fiber amplifiers will be used in these networks to compensate for the insertion loss of the optical switches and the transmission loss in the fibers. When the network is reconfigured and wavelength channels are added or dropped, cross -gain saturation in fiber amplifiers will induce power transients in the surviving channels, which can cause service impairment not known in electronically switched networks. As fiber amplifiers saturate on a total power basis, addition or removal of channels in a multi-wavelength network will tend to perturb other channels that share all or part of the route. The power of the surviving channels should be maintained constant in order to prevent unacceptable error bursts if, for example, the surviving channel power becomes too low to preserve adequate eye opening or exceeds thresholds for optical nonlinearities.

Fiber loss is a fundamental limitation in realizing long haul point-to-point fiber optical communication links and optical networks. One of the advanced technologies achieved in recent years is the advent of erbium doped fiber amplifiers (EDFAs) that has enabled the optical signals in an optical fiber to be amplified directly in high bit rate systems beyond Terabits.

Optical system can achieve much higher data rates than electronic system. The most important factors limiting the transmission distance in fiber optical communication systems is the optical power loss caused by scattering and absorption mechanisms in optical fiber. Electrical repeaters, which require optical-electrical signal conversionhavemade the systems more complex and increased their installation costs. The optical amplifiers that were developed in 1980s enable the optical signals to be directly amplified optically.

In recent years we have witnessed the introduction of many new technologies for optical transmission, such as wavelength division multiplexing (WDM), erbium doped fiber amplifier (EDFA), fiber Raman amplifier, etc. These technologies help to expand the capacity of global telecommunication networks dramatically. The underlying driving force for this vast expansion is an ever-present human ambition to move forward, for example, from a mere text-based Email system to the world wide web (WWW), from voice communication (including _xed line and wireless communication) to voice over IP to on-line video conferencing, from online chatting to on-line gaming. All these developments require more and more network capacity.

An erbium-doped fibre amplifier (EDFA) is an in-line optical amplifier that is currently widely used in wavelength-division multiplexing (WDM) optical networks [3], [4]. In WDM applications, the EDFA gain is insensitive to the signal modulation of each wavelength channel. Indeed, it is this characteristic that makes EDFA's so attractive for WDM applications. However, large changes in the EDFA gain result when the total input signal power changes abruptly. The most frequent causes of abrupt changes in the input signal power are dynamic network reconfigurations and component failures. When the input signal power is abruptly changed, a transient EDFA gain excursion is observed according to the rule that the gain increases (decreases) in the event of a decrease (increase) in the total input signal power. The transient EDFA gain excursions adversely affect the quality of service that the network operators are able to guarantee [1], [2]. For this reason, the transient EDFA gain excursions need to be mitigated by dynamically controlling the EDFA gain.

The internal interconnect is for connecting the transmitter modules to the receiver modules. Optical fibers connect the outputs of the transmitters to optical combiners, then to wavelength routing networks. Amplifiers are used following optical combiners to compensate for the splitting loss of the space switches. There are two ways to compensate for the system loss. One way is to use an optical amplifier as a power booster right after the external modulator. The alternative is using an EDFA to amplify multichannel WDM signals after each optical combiner of the space switches. With a low input power, the EDFA can provide a higher gain. EDFA's are also assumed to be gain-flat within the WDM wavelength range and their saturated gain is calculated with the average power because of their long carrier lifetime of about 10 ms.
EDFA offers very efficient amplification at the third transmission window and conventional(C) band (1530-1565nm) can be amplified using EDFA. Erbium Doped Fiber Amplifiers (EDFA) made by doping the silica fiber with erbium ions can operate in a broad range within the 1550 nm window at which the attenuation of silica fiber is minimum and therefore it is ideal for the optical fiber communication systems operating at this wavelength range. The erbium-doped fiber amplifier (EDFA) is a key component of wavelength-division-multiplexing (WDM) optical transmission systems. Since each span in a transmission system has a different attenuation, the EDFA gain must change according to the optical power level input into the amplifier. In such an EDFA, the population inversion level averaged along the erbium doped fiber (EDF) is kept constant to maintain a flat gain condition. The average population inversion determines the EDF gain per unit length and EDFs with different lengths have different flattened gain spectra, which are the optimized gain spectra for WDM signal amplification.

CONFIGURATIONS OF EDFA

Part of the work explores the research and the previous studies that are relevant to the proposed topic. In addition, it discusses the different configurations of the EDFA and its effect on the NF and gain amplifier. There are varieties of configurations of EDFA which are dependent on the kind of application. Generally, from the pass until present, studies on the EDFA can be divided according to configuration into stages and passes as follows:

ONE STAGE EDFA

The one-stage EDFA configuration which means only one EDF that works as an active area. The one-stage can be a single-pass or double-pass configuration .

Single- pass

The basic single pass (SP-EDFA) module or configuration comprises one or two pump laser diode (LD) modules with fiber output, and also one or two (WDM) to collect the light with pump power. Furthermore, input and output isolators, and the active medium (EDF). All the optical components have single mode fiber (SMF) pigtails and are spliced together to form an EDFA module as shown in Figure 1a. Chun et al. (2003) proposed configuration for automatic gain control of optical EDFA that uses novel dual control lasers optical. The output power change of the surviving signal reduces to 5.7% when 1546 nm signal are added/dropped at 1 kHz. Meanwhile, the configuration is flexible and the clamped-gains can be tuned in the range of 13.5 to 31.5 dB. This method has some advantages such as, the grating resonance wavelengths can be tuned by bending the fiber section that contains the grating. Mrinmay et al. (2007) investigated the optical gain and NF for multichannel amplification in EDF under optimized pump condition. They experimentally studied the optical gain and NF for simultaneous multi-channel amplifications in EDFA under optimized pump condition for different input signal levels of optimized fiber lengths. It was observed that the gain and NF values primarily depend on the pumping configurations and produced optimum result at bi-directional pumping, whereas the gain-spectra and noise characteristics depend mainly on the population inversion level along the fiber length. Moreover, EDFA which is the population inversion along the fiber length was controlled by varying the injected pump power. However, Bi-directional pumping results the best combination of gain and NF of EDFA. While co-propagation of pump and signal produces the best noise performance. Moreover, at higher input signal power levels, the signal significantly depletes the inversion beyond the pump's ability to replenish it and the NFs increase rapidly with signal power. The authors have taken another direction which integrated (SP-EDFA) with a chirped fiber Bragg grating (CFBG) to compensate both the attenuation and dispersion as well as considering the high gain and low NF by very low remote pump power .Therefore, the numerical results play an important role in designing an optimized remotely pumped SP-EDFA for the repeater-less long haul OFCS from the point of view of economic usage of pump power (Nadir et al., 2007b).

Double pass

The basic double pass (DP-EDFA) is a state in which signal will pass two times through active medium, the Erbium doped fiber (EDF). Theoretically it is proven that the double pass method will enhance the gain twice as compared to the single pass (Desurvire, 1994). Rosolem et al. (2008) investigated simple double pass configuration by using a single commercial EDFA for S-band application as well as amplifier spontaneous emission (ASE). The design shows excellent gain performance when compared with

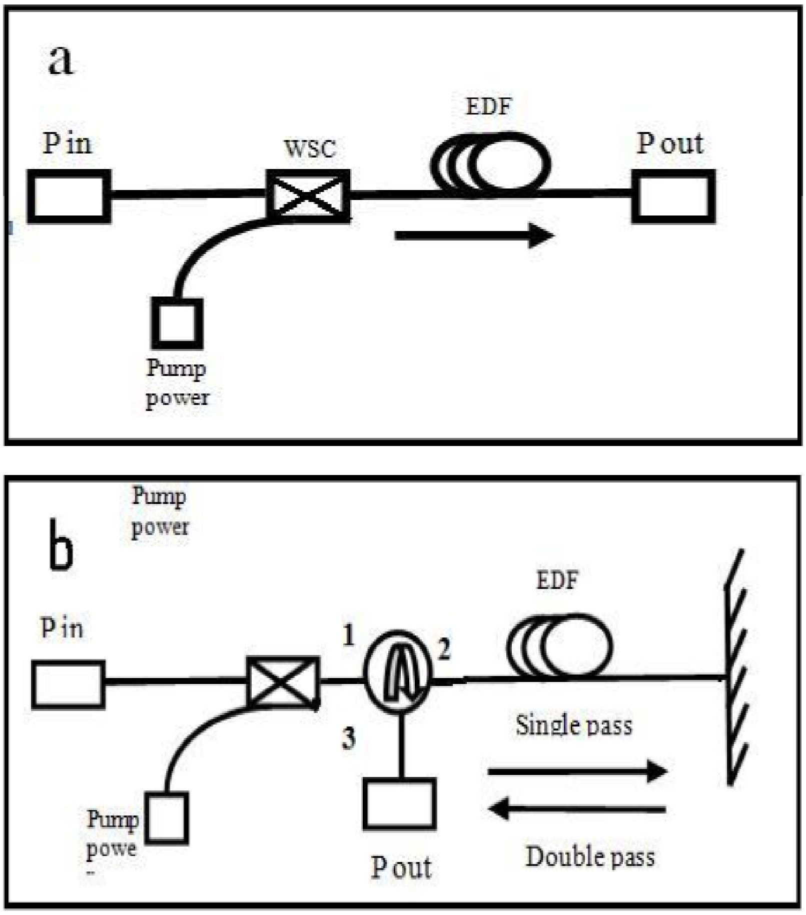

Figure 1. (a) One -stage single pass (b) one- stage double pass.

TWO STAGES OF EDFA

The two-stage EDFA configuration can be double-pass, Triple-pass or quadruple-pass. In Juhan (1999) a novel highly efficient EDFA structure for long bandwidth from 1570-1610 nm band signal amplification is proposed. Four types of L-band silica-based EDFA are experimented; 1. Type I: conventional forward pump. 2. Type II: conventional backward pump. 3. Type III: unpumped EDF section before forward pump. 4. Type IV: unpumped EDF section after backward pump. The result shows that the type III got the higher gain and the lower NF 22 and 5 dB, respectively as compared to the other types. It is to compare the rest according to the gain and NF which are dramatic increase in power conversion efficiency (maximum from 11.7 to 25.7%) and small-signal gain (4 dB maximum) that had been shown when compared with other EDFA structures with the same pump power and EDF length. However, the configuration is relatively suffering from a small penalty on NFs. In Belal et al. (2011) authors proposed a novel wide-band dual function fiber amplifier. This novel configuration at low single power of -30 dBm is able to achieve gain up to 32.64 dB and noise figure of less than 5 dB.

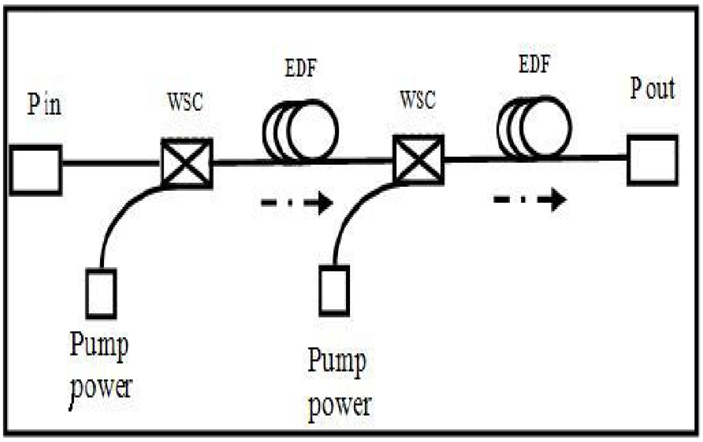

Figure 2. Two-stage double pass

Erbium is generally preferred because of the inherent properties associated with it. Erbium ions have quantum levels that can be stimulated to emit in the least power loss 1540nm band. This property of Erbium ions made it suitable to construct good quality high gain amplifier. Moreover the property of Erbium is that its quantum levels allow it to get excited by 800nm or 980nm signal which is carried by the glass fiber without much loss and which does not lie near the signal wavelength. Another important property of Erbium is its solubility with silica which will make it easier to get doped into mixtures for making glass fibers. Amplification is achieved by stimulated emission of photons from dopant ions in the doped fiber. The pump laser excites ions into a higher energy from where they can decay via stimulated emission of a photon at the signal wavelength back to a lower energy level. The excited ions can also decay spontaneously (spontaneous emission) or even through nonradiative processes involving interactions with phonons of the glass matrix. These last two decay mechanisms compete with stimulated emission reducing the efficiency of light amplification. The amplification window of an optical amplifier is the range of optical wavelengths for which the amplifier gives the amount of usable gain which does not include noise.Erbium has several important properties that make it an excellent choice for an optical amplifier. Remember that there are several very specific bands (wavelengths) that fiber optic cables can carry. Erbium ions (Er^{3+}) have quantum levels that allows them to be stimulated to emit in the 1540nm band, which is the band that has the least power loss in most silica-based fiber. That gives them the ability to amplify signals in a band . Erbium's quantum levels also allow it to be excited by a signal at either 800nm or 980nm, both of which silica-based fiber can carry without great losses, but aren't in the middle of the signal wavelengths. Those bands are also far enough away from the signal bands that it is easy to keep the pump beam and the signal beam separated.

APPLICATION

Erbium-doped fiber amplifiers are an important technology for lightwave voice, video, and data transmission [7],[8]. The passage of the 1996 Telecommunications Act and the growth of the Internet have sparked intense demand for expanded bandwidth in all network layers, resulting in significant advances in Erbium-Doped Fiber Amplifier (EDFA) technology. This two-volume set combines Erbium-Doped Fiber Amplifiers: Principles and Applications, an important exploration of the then-infant technology of erbium-doped fiber amplifiers, and Erbium-Doped Fiber Amplifiers[: Device and System Developments, a new volume designed to expands the reader s conceptual understanding of EDFAs and cover the developmental issues of EDFAs that are relevant to modern telecom applications

EDFA PARAMETRS FOR SYSTEM ANALYSIS

:1 **Noise Figure**

The analysis of noise in optical systems is sufficiently complex that it can be characterized either with simple engineering formulae or by a thorough quantum theoretical approach. The optical noise figure is a parameter used for quantifying the noise penalty added to a signal due to the insertion of an optical amplifier. That is, before light enters an amplifier the signal to noise ratio SNRin, after amplification it is SNRout. Thus, optical noise figure can be defined as:

$$NF = 10log_{10}\frac{SNR_{in}}{SNR_{out}}$$

It is the most basic equation of noise figure.

Noise factor equation is related to gain is shown as

$$F = 2k\mu_{eff}\frac{(G-1)}{G} + \frac{1}{G}$$

The corresponding noise figure is then given as

$$NF = 10log_{10}(F)$$

Noise figure vs Optical gain plot:
For 2-stage EDFA:

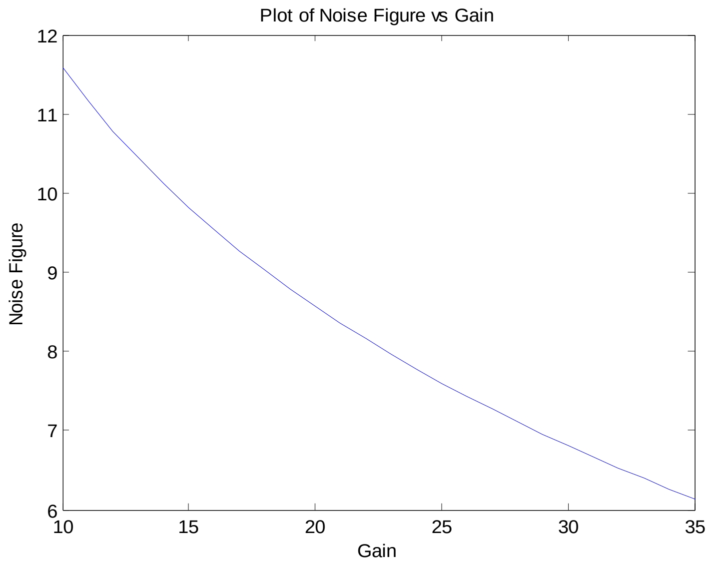

Fig.5 Gain VS Noise Figure

It is the most basic graph of Gain vs noise figure.it simply showsthat gain is inversely proportional to noise figure.

CONCLUSION

In this paper, we described the basic analysis of gain in terms of noise figure.any system which has high gain is its advantage.as we know that gain is inversely proportional toNoise figure,so as the noise figure will decrease so gain will Improve.The gain of the system was 10 dB initially then theNoise figure was 11.5 dB approx but when we have increased the gain upto 35 dB then the noise figure suddenly decrease upto 6.1 dB.

REFERANCES

[1] M. A. Mohammed," Theoretical Analysis of a Double Stages Erbiumdoped Fiber Amplifier" 978-1-4244-6235-3/10/$26.00 ©2010IEEE.

[2] H. Masuda, "Review of wideband hybrid amplifiers," in Tech. Dig. OFC'00,2000,PP.2-4.

[3] P. B. Hansen, L. Eskildsen, S. G. Grubb, A. J. Stentz, T. A. Strasser, J. Judkins, J. J. DeMarco, R. Pedrazzani, and D. J. DiGiovanni, "Capacity upgrades of transmission systems by Raman amplifier," IEEE Photon. Technol. Lett., vol. 9, pp. 262–264, 1997.

[4] M.-S. Kao and J.Wu, "Extending transmission distance of high-density WDM systems using post transmitter fiber Raman amplifiers," J. Lightwave Technol., vol. 9, pp. 394–399, 1991.

[5] D. N. Christodoulides and R. B. Jander, "Evolution of stimulated Raman crosstalk in wavelength division multiplexed systems," IEEE Photon. Technol. Lett., vol. 8, pp. 1722–1724, Dec. 1996.

[6] L. F. Mollenauer, J. P. Gordon, and M. N. Islam, "Soliton propagation in long fibers with periodically compensated loss," IEEE J. Quantum Electron., vol. QE-22, no. 1, pp. 157–173, Jan. 1986.

[7] M. N. Islam, "Raman amplifiers for telecommunications," IEEE J. Sel. Topics Quantum Electron., vol. 8, no. 3, pp. 548–559, May/Jun. 2002.

[8] J. Bromage, "Raman amplification for fiber communications systems," J. Lightw. Technol., vol. 22, no. 1, pp. 79–93, Jan. 2004.