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 VS PUMP POWER

[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 gain and pump power.in this simulation is done in matlab. Through which we will see how gain changes wrt pump power.

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 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 wavelength division (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 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

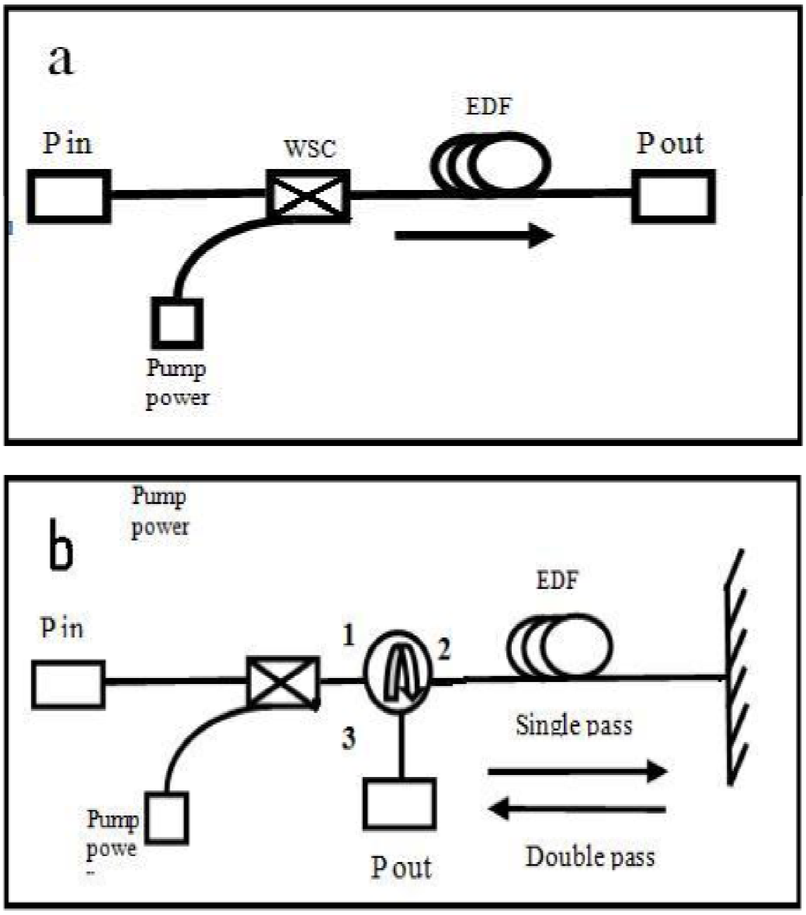

Figure 1. (a) One -stage single pass (b) one- stage double pass.

TWO STAGES OF EDFA

The two-stage EDFA configuration can be double-pass, Triple-pass or quadruple-pass figure 2. 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.

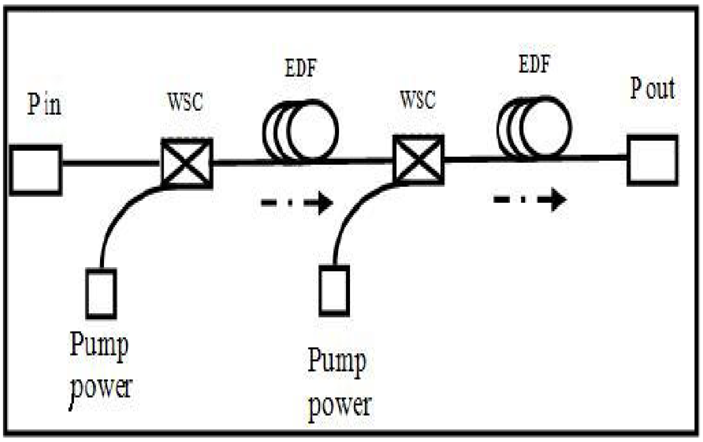

Figure 2. Two-stage double pass

THREE STAGES OF EDFA

The three-stage EDFA configuration means three EDFs that are working as active areas. The three-stage can be represented as follows; triple-pass with signal passes three times on EDFs configuration as shown in Figure 8. Theoretical investigation has been done (Zhi et al., 2003) Naji et al. 4683 where optimization of a two-pump, three-stage L-band EDFA with high-loss inter-stage element was based on a reliable numerical model. By optimizing the EDF length of each stage properly, both high-output gain and uniform NF profile can be derived even with high-loss inter-stage devices which are about 20.7 and 5.5 dB, respectively. In addition, in a WDM channel add/drop scenario, the former pump power and population inversion should be kept high to avoid NF degradation. While in Qiang et al. (2004) authors proposed novel three-stage L-band EDFA structure with ASE pumping. The three configurations with three designs which are the first is conventional signal-stage EDFA, the second one is structure introduced and the third is the new proposed. The numerical results under pump power 980 nm for various structures showed that gain and NF are 11, 19, 28.9 dB and 5.3, 9, 3.6 dB, respectively. As a result, the new proposal performed excellent with respect to other structures where 28.9 dB gain with only about 1 dB gain ripple and less than 3.6 dB NF (from 1570 nm to 1605 nm) is provided when the input signal is fixed at -30 dBm. Chin-Feng and Likarn (2007) presented an idea of using residual pump power for implementation of low-noise and high-gain L-band EDFAs by using a single 1480 nm pump laser and -30 dBm signal power for all experiments (Chin et al., 2007). In addition, reviews of two conventional L-bands EDFA systems have been reported to be able to enhance pump conversion efficiency (Juhan, 1999). The result at wavelengths (1570 and 1590 nm) showed that the first conventional L-band EDFA system got a gain of about 29 dB and NF of about 6 to 7 dB. The second conventional L-band EDFA system got a gain about 27 dB and NF about 6 to 7 dB. The new configuration comes from modifying the second conventional L-band EDFA system to get higher gain with acceptable NF where a new EDF is added between the two EDFAs, second conventional would definitely deteriorate NF. The gain and the NF for the proposed three-stage EDFA are 36 dB and 4.3 to 4.8 dB, respectively which clearly shows the difference as compared to the first and second conventional L-band EDFA system. However, adding new EDF that help to reduce the NF produce little positive gain for signals which increased the cost. From the previous work it is clear that pump power plays very important role which have effect on gain and noise figure. Therefore optimsing the pump power is important in order to get higher gain and low noise figure. For example Nadir et al. (2007b) characterize the gain and NF at 1550 nm as a function of pump power using a 10 m long EDF as shown in Figure 9. Referring to Figure 9, for the increment of pump power from 5 to 14 MW, signal gain increases from 8.73 to 12.02 dB and NF decreases from 5.49 to 4.65 dB. On the other hand, for the increment of pump power from 14 to 60 MW, signal gain increases from 12.02 to 13.54 dB and NF decreases from 4.65 to 4.35 dB.

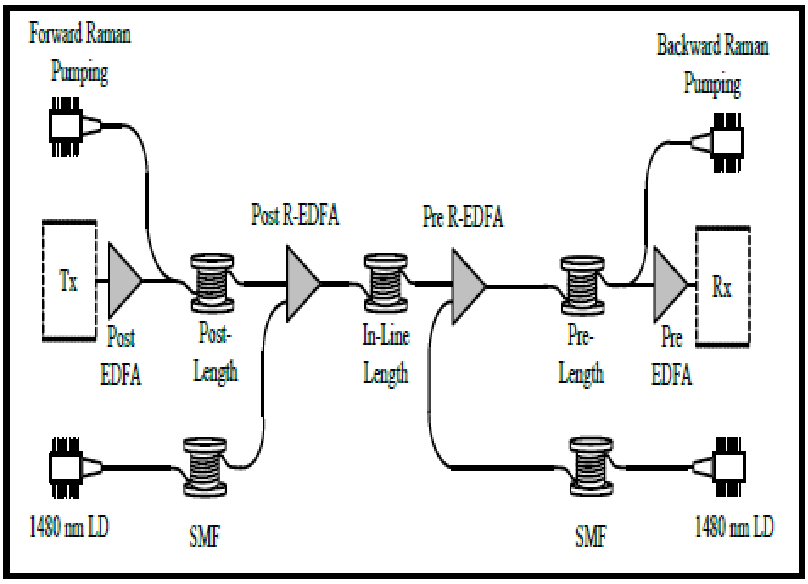

Figure 3. Configuration of optical transmission system.

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 a 800nm or a 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.

EDFA PARAMETRS FOR SYSTEM ANALYSIS

1 **Pump Power**

$$PumpPower = P_{sat} = \frac{(A.hv)/_{\lambda}}{(\text{sap} + \text{sep}) * \tau Qe}$$

sap and sep is erbium spectrum at pump wavelength, A is doped core area, Qe is quantum efficiency of pump, which is less than one for Er doping.

τ =0.77e-3 is spontaneous decay rate of excited ions.

$$A = \pi(\frac{d_{core}}{2})^2$$

Frequency of pump photons

nup = $\frac{c}{w_{lp}}$

w_{lp} is pump wavelength

d_{core} doped core diameter.

h = 6.62606957x$10^{-34}$is planck's number

c = 3x10^8 is speed of light in vacuum

Gain at different wavelength:

$$G = 4.34\frac{Q_e(s_{al}(\lambda)+s_{el}(\lambda))\tau.Pa}{Ahv-\gamma Ns_{al}(\lambda).L-loss} \qquad (1)$$

Where Pa is change in pump power ie. absorbed power, L length of EDFA doped fibre.

$\gamma = 1 - e^{-(2(b/w)^2)}$is overlap integral assuming Gaussian flux distribution

b = dCore/2 is radius of dopant in core

w = dField/2 is radius of flux field travelling along core

$$N = \frac{doping}{10^6} N_{glass}$$

doping = 80;

$$N_{glass\ AL_2O_3} = \frac{4x\,10^6}{102x1.6726x\,10^{-24}}$$

Plot of Gain vs Pump Power:

Gain is plotted against wavelength at fibre length L= 8.2 m and L=17m

It is the most basic plot of Gain vs Pump power .Gain is directly proportion to pump power.from the equation above 1 we can easily analyse that the gain is increasing so pump power is also increasing at a great pace

Figure4 shows the plot obtained between gain and pump power both are increasing simultaneously.as they both are directly proportion to each other.

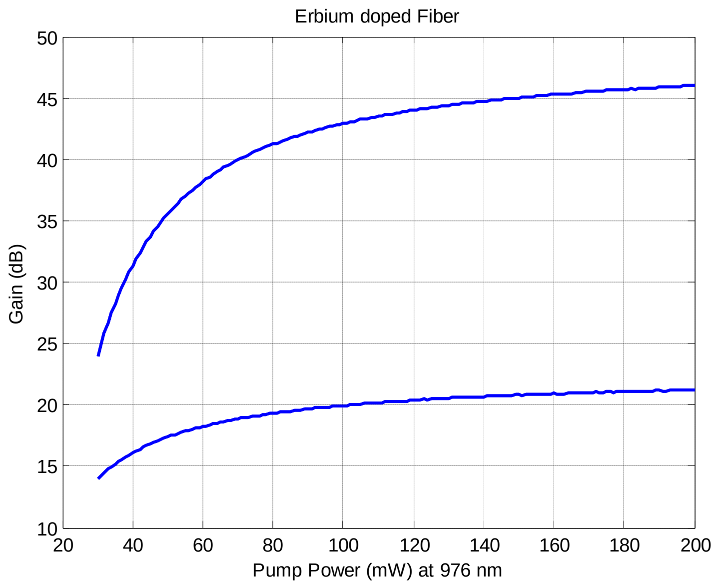

Figure 4 Gain vs pump power

CONCLUSION

In this paper, we described the concept and advantage of the gain in terms of pump power.as the pump power increased gain also increased.this is shown in AS the fiber length was 8.2m the pump power was 40 then the gain was 16dB,when the pump power was 200 then the gain was23.3 dB so it clearly so as the pump power increase so gain also increases.

REFERENCES

[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. Light. Technol., vol. 22, no. 1, pp. 79–93, Jan. 2004.