VOL. 10, NO. 5, MARCH 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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ASE NOISE ANALYSIS IN CASCADED EDFA-EYCDFA

S. Semmalar[1] and S. Malarkkan[2]
[1]SCSVMV University, Kanchipuram, India
[2]Manakula Vinayagar Institute of Technology, Puducherry, India
E-Mail: subbusem@gmail.com

ABSTRACT

The scope of this paper is to analyze ASE (Amplified Spontaneous Emission) noise power using the simulation model EDFA(Erbium Doped Fiber Amplifier) cascaded with EYCDFA (erbium-ytterbium co-doped fiber amplifier) in 4-16 channels of transmitters combined by optical multiplexer and sent the output to EDFA in series with EYCDFA in single backward pumping using the wavelength of 980nm. This simulation model performance was analyzed with the parameters Gain, forward output signal power and ASE noise was measured and the values are tabulated. The simulation model consists of 2- 16 channels of RZ transmitter and 2- 16 channels of NRZ transmitter's outputs were multiplexed with optical multiplexer and multiplexed signal sent to cascaded Erbium amplifiers with pumping CW (continuous wave) Laser source with wavelength 980nm and Filter. The resulting model accurately represents EDFA Gain and output signal power and ASE noise. Simulation results shows that by choosing careful fiber length 20m and pump power 1mw in single pumping gives ASE noise 0.005mw using EDFA and EYCDFA gives zero mill watts.

Keywords: ASE noise power, EDFA, EYCDFA, optical fiber communications, single pumping, wavelength optical multiplexer.

1. INTRODUCTION

As the demand of high speed internet services is increasing, an answer to long distance communication system with high bit rate transmission is optical communication systems which employ Optical amplifier that can be used as a medium for telecommunication and networking. The light propagates through the optical fiber with little attenuation compared to electrical cables. An optical fiber amplifier is a device that amplifies an optical signal directly without the need to first convert it to an electrical signal in optical fiber communications, EDFA's are mostly used as preamplifiers with multi channel amplification without cross talk and also multi gigabit transmission rates by low bit errors [1].

Most important element of EDFA technology is the Erbium Doped Fiber (EDF), which is a conventional Silica fiber doped with Erbium. Erbium-doped fiber amplifiers have attracted the most attention because they operate in the wavelength region near 1.55µm The deployment of EDFA in WDM systems have revolutionized the field of optical fiber communications and led to light wave systems with capacities exceeding 1 Tb/s.

a) Basic principle of EDFA

Amplification in an Erbium – doped fiber amplifier occurs through the mechanism of stimulated emission. When the Erbium is illuminated with light energy at a suitable wavelength (either 980nm or1480nm) it is excited to a long lifetime intermediate state level 2 following which it decays back to the ground state by emitting light within the 1500-1600 nm bands [2]. If light energy already exist within the 1500-1600nm band, for example due to a signal channel passing through the EDF, then this stimulates the decay process (so called stimulated emission), resulting in additional light energy.

A pumping signals can co propagate with an information signal or it can counter propagate. Thus, if a pump wavelength and a signal wavelength are simultaneously propagating through an EDF, energy transfer will occur via the Erbium from the pump wavelength to the signal wavelength, resulting in signal amplification. A wavelength far from the emission peak around 1530nm has to improve the amplification characteristics of the L-band and C-band EDFA. An important issue is the selection of a proper pump wavelength or a suitable pumping configuration. The pump wavelength dependence of the amplification characteristics of the EDFA has been reported mainly in 800-, 980-, and 1480-nm bands and now the 980- and 1480-nm bands, are mostly used for the L- band and C-band EDFA's

b) EYCDFA

This block models the operation of an erbium-ytterbium co-doped fiber amplifier (EYCDFA) shown in Figure-1. The model supports component specifications at different levels of complexity, as well as a variety of pump and signal configurations. Physical EYCDFA model uses the Forward-propagating optical signals are launched into the EYCDFA via the first input node, while backward-propagating signals enter via the second input node.

Optical multiplexer components can be used to combine signals and pumps at either input. The EYCDFA output is available at the output node, and includes any signals, pumps, and ASE noise that are exiting the amplifier. The EYCDFA may also be used to simulate bidirectional signal propagation, in which case input signals are expected at both input nodes, and an additional backward output appears at the backward output node.

In order to describe the interaction of the erbium and ytterbium ions with local signal, pump, and noise powers, the model uses a set of rate equations for erbium

VOL. 10, NO. 5, MARCH 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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and ytterbium ion densities in each atomic level. In most EYCDFA applications, the dopants' long metastable lifetimes act to eliminate any significant transient changes in the atomic level

Populations, thereby allowing us to set the time rate-of change.

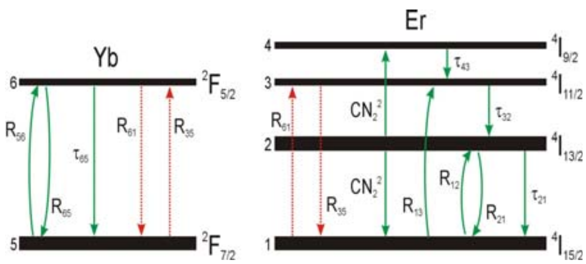

Figure-1. Erbium and ytterbium atomic manifolds.

c) Signal power in an EDFA

The output signal power is calculated as

$$Pout = Pin \times G \tag{1}$$

Where G is the EDFA (Amplifier) power gain and Pin is the input signal power. The most important feature of the EDFA is gain as it determines the amplification of individual channels when a WDM signal is amplified [5].

The amplified output signal power is degraded due to the ASE (Amplified Stimulated Emission) noise and the output signal power increases due to the stimulated emission and this is due to population inversion and population inversion is due to pumping power.

The gain of the EDFA is limited by the fact that there are a limited number of Erbium ions in the core. Increasing the Pump power beyond the point where all the ions are excited cannot produce more gain and thus saturation occurs. An erbium doped amplifier can amplify light wavelength ranging from app 1500 nm to more than 1600 nm.

Two such bands are in use today. One is the C-band (Conventional band) which occupies the spectrum from 1530 nm to 1560 nm and the second is L-band (Long wavelength band) which occupies the spectrum ranging from 1560 nm to 1610 nm. Most EDFA work in the C-band. Noise is the second most important characteristic of an optical amplifier.

d) ASE noise

The principal source of noise in EDFAs shown in Figure-2 is Amplified Spontaneous Emission (ASE), which has a spectrum approximately the same as the gain spectrum of the amplifier.

Optical noise of an amplifier is inherently due to a random spontaneous emission amplified in a fiber medium. ASE spectrum is quite broad. Total ASE power over the gain bandwidth is:

$$P_{sp} = n_{sp}(G-1)h\nu(\Delta\nu) \tag{2}$$

Where *G* being the amplifier gain and

$$n_{sp} = \frac{N_2}{N_2 - N_1} \tag{3}$$

The n_{sp} denotes inversion factor. The carrier density is N_1, and N_2 is its value at transparency.

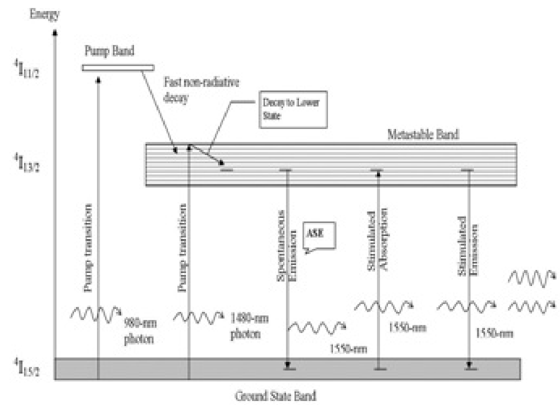

Figure-2. EDFA structure.

e) CW laser

This model produces the optical signal output of one or more CW lasers. It is most commonly used in conjunction with the external modulator model to encode a binary signal upon the CW source. In this model, the CW source is characterized completely by its power, wavelength, line width, relative intensity noise (RIN) and phase

An erbium –doped fiber is the active medium of an EDFA. The two most important elements in order to produce high amplified output signal power in L-band EDFA are the length of EDF and the pump power both of which have been analyzed in this paper.

This paper is organized into six sections. In section II Literature Review of this work, while section III presents the methodology and the proposed work. Section IV demonstrates the model Simulation details. Section V presents the results and discussions. Finally, the paper is concluded in section VI.

2. LITERATURE REVIEW

This paper [1] presents a composite EDFA configuration which incorporates an optical isolator and investigated highly efficient amplifier configurations with high total gain and narrow ASE spectrum. This paper [4] designed the broadband EDFA using dual forward pumping and results to increased gain and gain bandwidth. This paper [6] proposed an EDFA pumped in the 660nm and 820nm bands wavelength gives enhanced gain. This paper [7] amplifier's gain and power noise which appear in the signal to noise ratio expression, are computed in terms of the internal parameters from simulations and are shown to contribute to its improvement. The paper [11] developed an analytic model for gain modulation in

VOL. 10, NO. 5, MARCH 2015 ISSN 1819-6608
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EDFAs. The analytic model was then used to explore the effect of mean input signal power (EDFA gain saturation) and dependence on signal wavelength. It was found that pump to signal modulation index increases with signal power (saturation), rising to a maximum and then decreasing as EDFA become deeply saturated. The reverse is true of the signal to signal modulation index. The paper [14] proposed a average power analysis technique similar to that used for semiconductor optical amplifiers. In this paper [13] analyzed gain versus pump power for EDFA. This paper [15] allows network designers to determine the tolerances by which the signal power levels may deviate from their pre designed average values. This paper [16] with the introduction of two band EDFA architecture provides high output power and low noise figure. This paper [18] ASE broadband light source and EDFA gives the emission spectrum and ASE noise increases with pump power. This paper [19] cascaded model analyzed using the gain

3. METHODOLOGY

In this work, the EDFA and EYCDFA are to be cascaded and transmits the signals by the four- 16 channels optical transmitters gives the analysis of ASE noise, forward signal output power, Gain, noise figure from the simulation model of EDFA and EYCDFA are connected with single backward pumping of 980nm with EDFA Length 20m have been simulated with optical combiner blocks and a high Performance approach is presented that has not been used in this manner before such design. Erbium doped fiber amplifiers (EDFA) employed in such systems have been shown to incur system impairment.

a) Applied methodology

The applied methodology is based on single backward pumping approach. Each block in the architecture was added in the model, tested and later those blocks were assembled and were added to compose the complete system and then simulated and tabulated the parameters (Forward output signal power, Gain, noise figure and ASE noise) values.

b) Proposed work

Figure-3 shows the simulation model consists of the transmitters with 2-16 channels of RZ source and 2 - 16 channels of NRZ source generated a combined optical signals send to optical multiplexer and the multiplexed signal given to EDFA and EYCDFA cascaded amplifiers and given to optical filter to restrict the frequency.

Recently, lots of problems in bidirectional EDFAs were investigated, and various structure schemes of the EDFA were reported to overcome the problems, such as back reflections [3]. An automatic gain control (AGC) function for bidirectional EDFAs however, has been rarely reported.

This method has the advantage of providing optical fiber with few Erbium clusters because the Erbium is uniformly doped into silica soot perform in a vapor phase atmosphere. In order to attain highly efficient EDFA's, the three key factors outlined below must be considered

The first is the Erbium concentration effect on Erbium cluster generation in silica-based glass [4]. Compared with unidirectional transmission, bidirectional transmission over a single fiber has the advantage of reducing not only the number of fiber link, but also the number of passive components such as splitters and WDM multiplexers. It has already been confirmed that an increase in Erbium concentration causes deterioration in amplification efficiency [6].

4. MODEL SIMULATION

The simulation model, EYCDFA cascaded with EDFA using single pumping (980nm) shown in Fig 3 and Figure-4 shows the internal blocks present in Transmitter Tx_NRZ 16ch.

The parameters gain and forward and backward ASE noise has been measured with pump power 1mw and EDFA Length 20m from the simulation model and that has been tabulated and analyzed.

(Solid line in the simulation model denotes the equipments used, dotted line denotes the measurements). The gain spectrum of EDFAs can vary from amplifier to amplifier even when core composition is the same because it also depends on the fiber length.

The main difference between forward and backward pumping technique is that in the later one pump power and the signal beam propagate in opposite directions as compared to the forward pumping scheme.

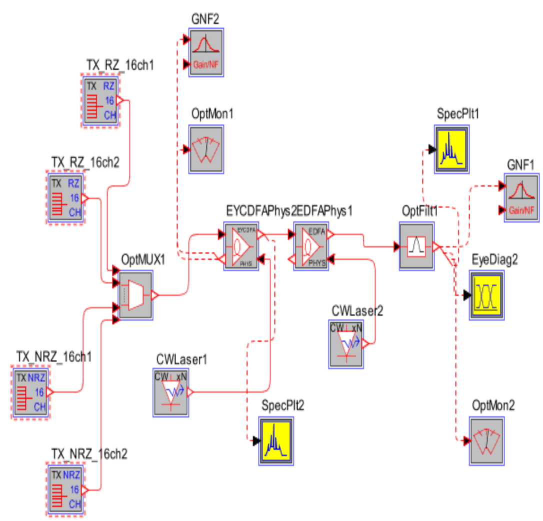

Figure-3. Simulation model of proposed work: EDFA cascaded with EYCDFA of single stage (forward) pumping.

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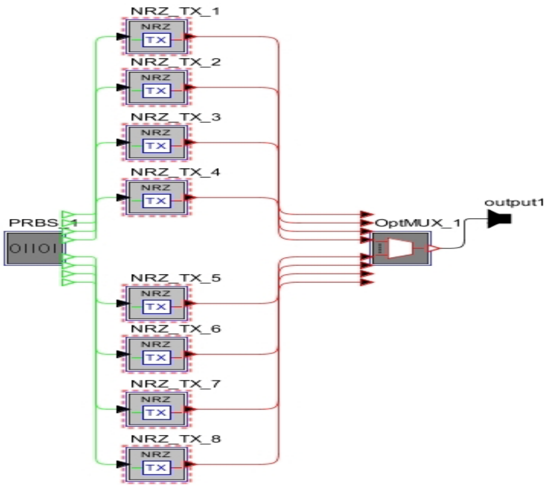

Figure-4. Single NRZ 16 channels Transmitter (look inside in simulation model as NRZ_TX16).

5. RESULTS & DISCUSSIONS

The results are taken from the output of EDFA and EYCDFA. EDFA output is shown in Figure-5, Figure-6 and Figure-7 and EYCDFA output is shown in Figure-1.8 and Figure-10. Figure-9 is the output amplified signal. Figure-7 and Figure-8 is the ASE power spectra at fiber ends taken from the output of simulation model.

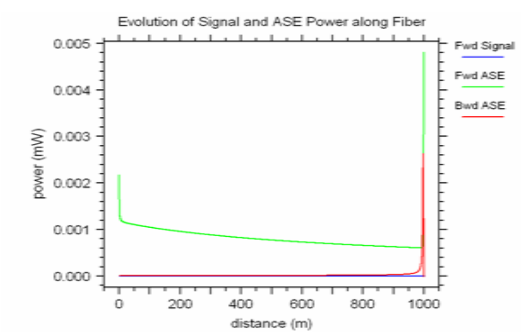

Figure-5. Simulated model of EDFA ASE Noise Development using single Pumping scheme.

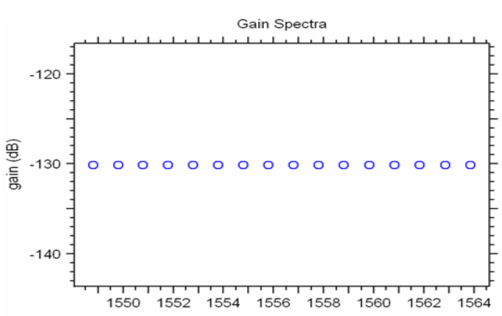

Figure-6. Simulated model of EDFA Gain using single Pumping scheme.

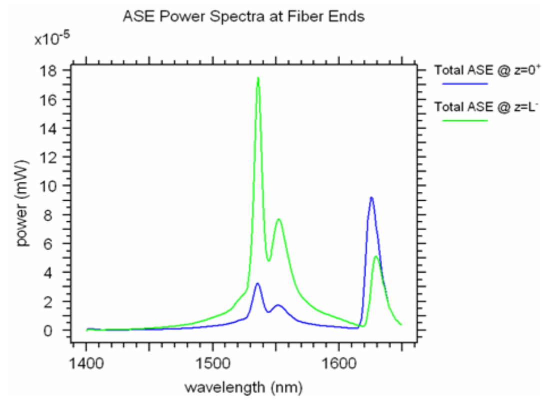

Figure-7. Simulated model of ASE Noise in EDFA at Fiber ends of the optical communication system.

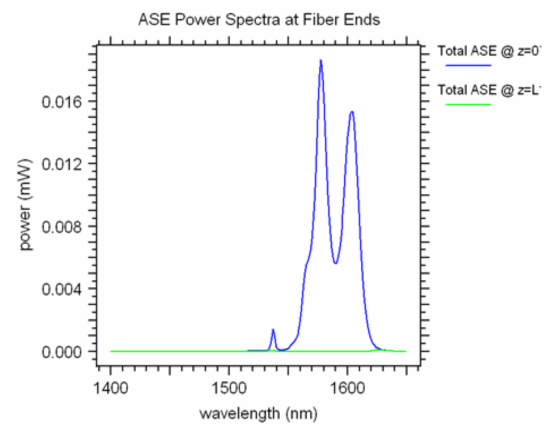

Figure-8. Simulated model of EYCDFA ASE Noise at Fiber ends of the optical communication system.

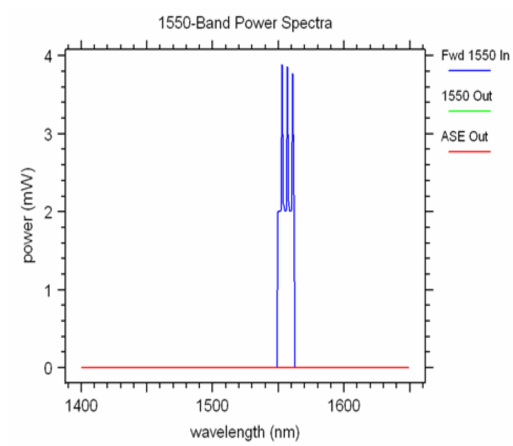

Figure-9. Output amplified signal spectrum characteristics of Cascaded simulation model with single pumping.

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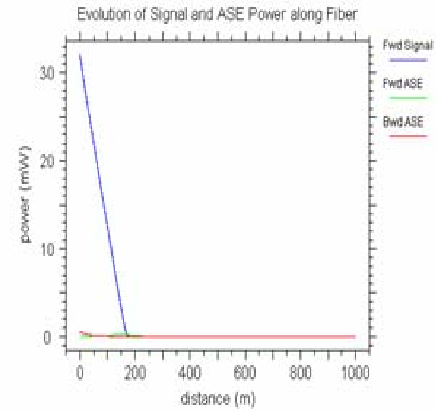

Figure-10. Forward Signal and ASE Noise Characteristics in EYCDFA.

Simulation results indicate that the EDFA gives maximum ASE noise than EYCDFA when input multiple channels were transmitted but EDFA gives maximum gain than EYCDFA.

Table-1.
RESULTS: Gain and ase noise in EDFA and EYCDFA

Parameters	Pump power=1mw EDFA length= 20m		
	EYCDFA	**EDFA**	**Remarks**
Gain (DB)	-130	-125	Decreases
Forward ASE noise (mw)	zero	0.005	ASE noise decreases
Backward ASE noise (mw)	zero	0.0025	ASE noise decreases

Table-1, shows the simulated values and are tabulated, Gain, forward and Backward ASE noise compared with EDFA and EYCDFA of length=20m.

The stimulated emission is due to population inversion and population inversion is due to pump power. Figure-11, shows the bar chart analysis of Gain and Figure-12 shows the ASE noise for single Forward and Backward pumping has been plotted for EDFA and EYCDFA.

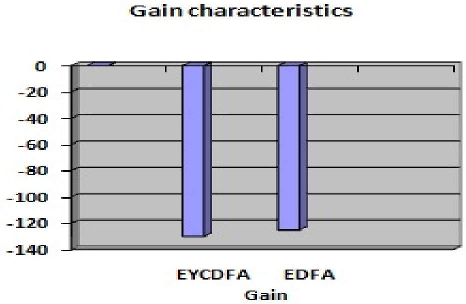

Figure-11. Bar chart analysis of gain in EDF A and EYCDFA for multiple transmitted channels.

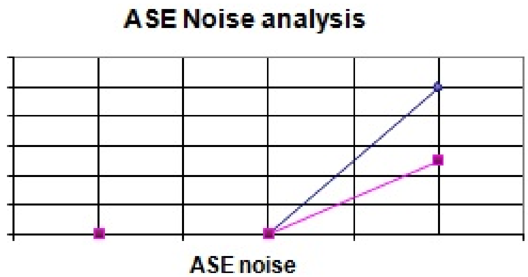

Figure-12. Plotted ASE noise analysis in EDFA and EYCDFA.

6. CONCLUSIONS AND FUTURE ASPECTS

In summarize, simulated the Cascaded model EDFA and EYCDFA with the input of 4- 16 channels transmitter output using single pumping scheme of 980nm. The results Gain and forward and backward ASE noise are taken from the output of EDFA and EYCDFA cascaded model was compared and analyzed. Gain increases in EDFA than EYCDFA but, ASE noise is zero in EYCDFA. Advancements in EDFA performance have allowed for longer fiber links between regenerators. To reduce the cost of regeneration efforts are ongoing to improve amplifier performance. Thus, we have shown that the proposed model of an Cascaded EDFA and EYCDFA utilizing single pumping technique was successfully simulated using optical multiplexer. The analyzed model is applicable in Network reconfiguration and Multi-vendor networks and also addition of new services and wavelengths. The results have been compared the EDFA output with the conventional EYCDFA parameter values. EDFA gives the maximum gain and EYCDFA gives minimum noise. So this Cascaded model is the best model for the communication purposes with high transmission capacity and for long haul applications. This simulation model will be enhanced by using Fiber Bragg grating filter gives maximum gain with reduced noise will be achieved.

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