ASE noise in Erbium Doped Fiber Amplifiers with Connector and Splice in Single Pumping Technique

S. Semmalar[1], S. Malarkkan[2]
[1]Research Scholar, SCSVMV Umiversity, Kanchipuram. India.
[2] Principal, Manakula vinayagar Institute of technology, Puducherry.

Abstract--**The scope of this paper is to analyze the ASE noise power in Erbium Doped Fiber Amplifier with Connector and Splice in Single and multiple sources (1520.25nm – 1617nm) in single pumping using the wavelength of 980nm. This Paper describes the simulation model of two EDFAs (Erbium Doped Fiber Amplifier) are connected with connector and splice and the performance was analyzed with the parameters Gain, noise figure, output signal power and ASE noise were measured before and after connector and splice and the values are tabulated . The simulation models consist of Input source, pump power coupled by WDM coupler and the two EDFAs are connected with connector or Splice gives the analysis of optimized signal power and ASE noise in the above mentioned simulation model. The simulation model consists of single source with wavelength (1550nm) and multiple sources with wavelengths (1520nm-1618nm), pumping source with wavelength 980nm, Isolator and Filter. Simulation results shows that by choosing careful fiber length 10m and pump power 0.12W in single pumping with splice technique provided 0.00064W optimized output signal power compared to other connector techniques.**

Keywords**—Output signal power, EDFA, Isolator, Optical Fiber Communications, Single Pumping, wavelength and WDM.**

I. INTRODUCTION

As the demand of high data speed networks is increasing, an answer to long distance communication system is optical communication systems which employ Optical fiber 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 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. Signal power in an EDFA

The output signal power is calculated as

$$Pout = Pin \times G \qquad (1)$$

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 measured from the output line is taken after the filter in the block diagram of Fig 1. And the input signal power is fixed as 0.001mw. This 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.

C. ASE Noise:

The principal source of noise in EDFAs shown in Fig. 1.1 is Amplified Spontaneous Emission (ASE), which has a spectrum approximately the same as the gain spectrum of the amplifier.

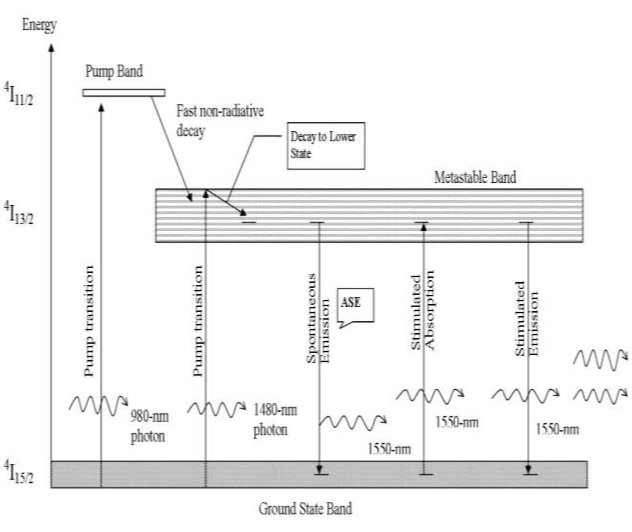

Fig. 1.1 EDFA Structure

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:

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

Where *G* being the amplifier gain and

$$n_{sp} = \frac{N_2}{N_2 - N_1} \quad (3)$$

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

D. Connector and Splice:

An optical fiber connector terminates an end of an optical fiber and enables quicker connection and disconnection than splicing.
The connectors mechanically couple and align the cores of fibers so light can pass. Better connectors lose very little light due to reflection or misalignment of the fibers. It is used in telephone company central offices, at installation on customer premises and in outside plant applications to connect equipment and cables.

Multiple channel components are designed to easily create sources with equally-spaced channels not tied to the ITU grid. The beginning and ending wavelengths can be specified, as well as the number of channels, which are evenly spread throughout the band. The power per channel can be set, and optionally every n^{th} channel can be automatically eliminated to simulate band edges.

Single channel components are simple representations of a single wavelength source, whose wavelength and power can be defined. Splice components are included to allow modeling of splice losses resulting from splicing fibers together in the assembly of an amplifier. While these losses can be lumped together with component insertion losses, it is more convenient for schematic display as well as for running iterative simulations to have a separate component. The operating wavelength ranges for both the signal and pump band can be defined, and separate splice loss values for the two bands can be specified. The signal band also covers the ASE band, so the signal minimum and maximum wavelength should define a range large enough to accommodate the entire ASE band as well.

Connector components are included to represent the use of optical connectors to mate two fibers instead of splices. The operating wavelength ranges for both the signal and pump band can be defined, and separate connector loss values for the two bands can be specified. Also, the return loss in both directions can be specified.

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.

II. 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 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 [17] Multi wavelength EDFA, ASE noise is investigated by connecting connectors and splice techniques. 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.

III. METHODOLOGY

In this work, the analysis of amplified signal power, Gain, noise figure and ASE noise from the simulation models of two EDFAs connected with connector and splice techniques with single and multi wavelength sources using single pumping of 980nm with EDFA Length 10m have been simulated with WDM 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 Wavelength Division Multiplexing (WDM) systems have been shown to incur system impairment.

A. Applied Methodology

The applied methodology is based on single forward 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 parameter (Output amplified signal power, Gain, noise figure and ASE noise) values.

B. Proposed Work

Fig 1. Shows block diagram of EDFA with single pumping using wavelength 980nm. The simulation model consists of the input single source with 1550nm and multiple sources with different channels (1520nm-1618nm) whose output is given to the isolator.

Further the output of the isolator is to allow the input signals only in forward propagation and the first pumping source has been multiplexed using WDM technique. This multiplexed signal is given to the EDFA where the signal is amplified to improve the gain. A wavelength-division-multiplexing (WDM) technique combined with erbium-doped fiber amplifier (EDFA) is essential for realizing high capacity light wave transmission and flexible optical networks.

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].

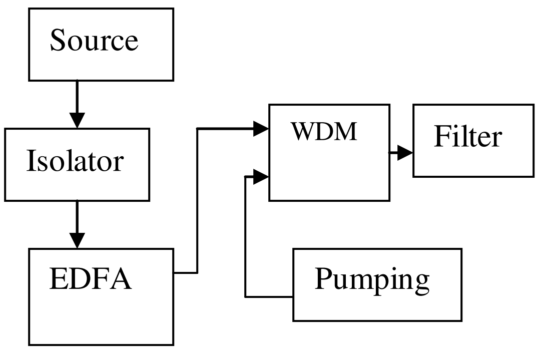

Fig 1.2 .Block Diagram of single stage (forward) pumping

In the above block diagram Fig 1.2, is the single forward pumping with EDFA gives maximum gain and reduced noise and has been compared with different input sources (Single and Multi wavelength).

The Erbium inversion level increases whenever EDFA uses less distance with the same pump power. For example same pump power 1w, the EDFA Length decreases from 120m to 50m, the fiber inversion level increases, this shows if the fiber inversion level increases the output amplified signal also increases, but inversion level is depends upon the pump power and wavelength.

Isolator allows the forward propagation for that there is no reflected signal. Compared with single stage techniques the model has an advancement of not cascading pumping sources in unidirectional way and hence a reduction in compactness. Filter here is to remove the unwanted wavelengths.

IV. MODEL SIMULATION

The simulation models, two EDFAs are connected with connector and splice techniques using single pumping (980nm) shown in Fig 1.3 and Fig 1.4.

The parameters Output amplified signal power, noise figure , Gain and ASE noise has been measured with pump power 0.12W and EDFA Length 10m from the simulation model and that has been tabulated and analyzed.

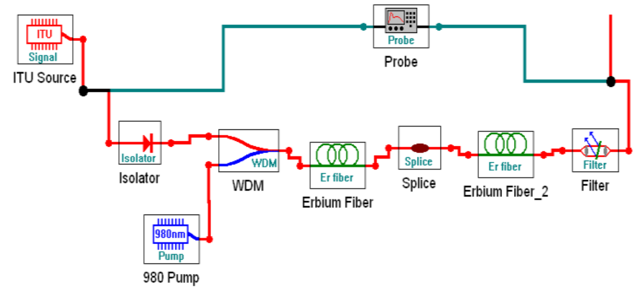

Fig 1.3. Simulated model of two EDFAs are connected with splice technique using single Pumping scheme

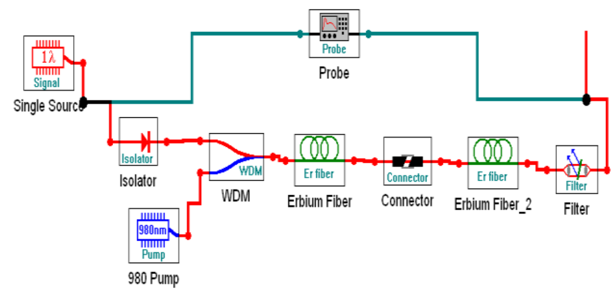

Fig 1.4. Simulated model of two EDFAs are connected with connector using single Pumping scheme

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. Fig 1.5 shows the Gain characteristics of EDFAs are connected by connector with single pumping scheme.

Wavelength-division multiplexing (WDM) technology employing erbium-doped fiber amplifiers (EDFA's) provides a platform for significant improvement in network bandwidth capacity and WDM will play a dominant role in backbone infrastructure supporting the next generation high-speed networks.

But due to complexity and variation in the output power level of various channels a limitation regarding change in gain profile of each channel makes the system in appropriate for dense multi channels.

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V. RESULTS & DISCUSSIONS

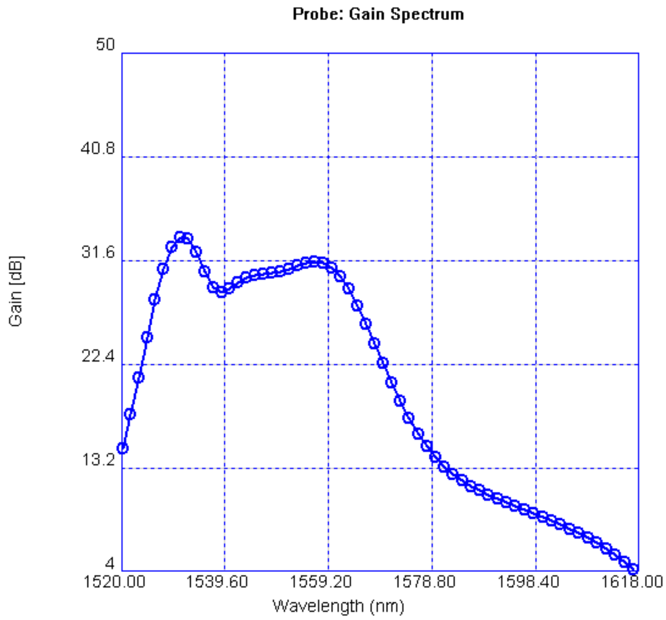

Fig.1.5 Gain characteristics of single pumping two EDFAs are connected by connector of length 10m and pump power 0.12w.

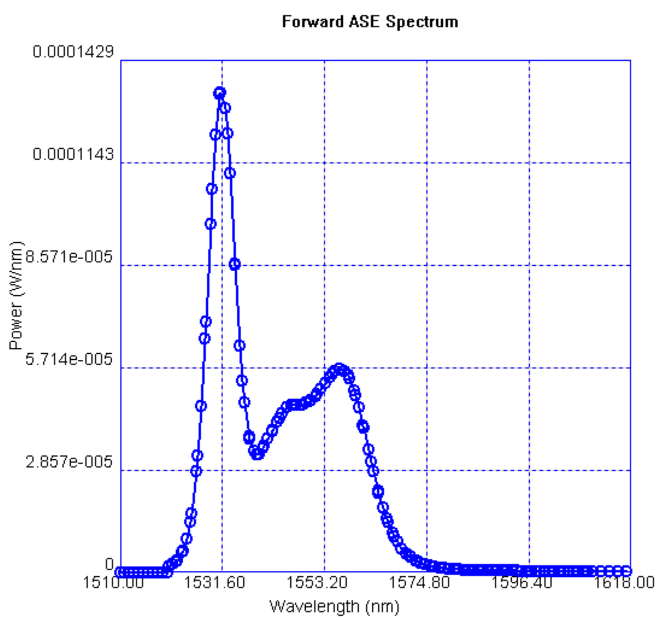

Fig. 1. 6. Forward ASE Noise Characteristics (after filter) of two EDFAs are connected by connector

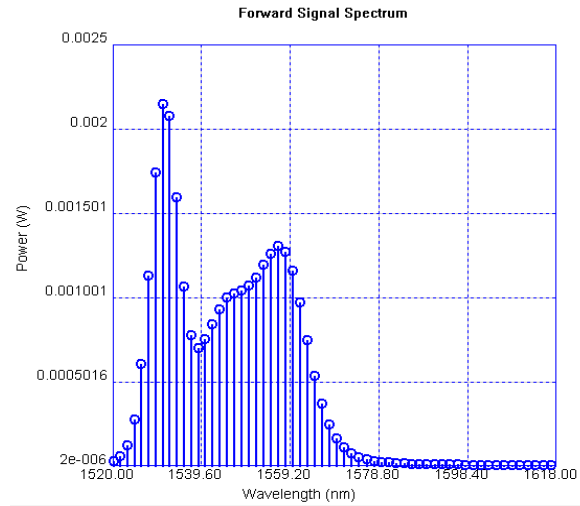

Fig 1.7. Forward Signal power characteristics in two EDFAs connected by connector

The simulation result shows output amplified signal power in watts when the input signal power is 0.001mw. Simulation results indicate that the amplified signal power from the transmitter output increases when pump power increases but amplified signal power decreases when EDFA length increases in Dual pumping technique with 980nm shows in table I.

TABLE I
RESULTS: SIGNAL POWER, NOISE FIGURE, GAIN AND ASE NOISE IN TWO EDFAS CONNECTED BY CONNECTOR AND SPLICE WITH SINGLE SOURCE (1550NM)

Parameters	**Single Source(1550nm) with 0.001W/nm, pump power=0.12W EDFA length= 10m**		
	With Connector	**With Splice**	**Remarks**
Gain (DB)	35	35.054	**Increases**
Noise Figure(DB)	5.3	5.4	Increases
Signal power (W/nm)	Before connector 0.0006	Before Splice 0.0006	**Maintained**
	After connector 0.0006	After Splice **0.00064**	**Increases in splice**
	After filter 0.00317	After filter **0.0032**	**Increases in splice**
ASE noise	Before connector 0.00068	Before Splice 0.0007	ASE noise increases
	After connector 0.00068	After Splice 0.00078	ASE noise increases
	After filter 0.00143	After filter 0.00148	ASE noise increases

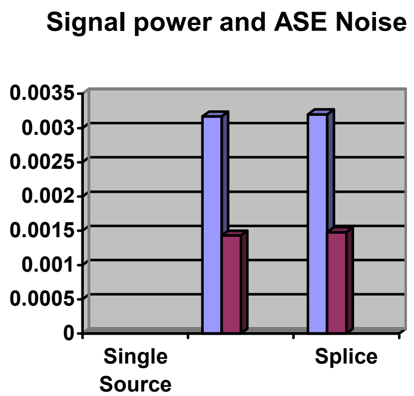

Fig 1.8. Bar chart Output amplified Signal Power and ASE noise in single pumping analysed with single source of 1550nm

Table I, Table II shows the simulated values and are tabulated, amplified output signal power, ASE noise compared with single and multiple wavelength sources using single pumping technique for different connector and splice the EDFAs length=10m.

Fig 1.6 and 1.7 shows the Signal power and ASE Noise Characteristics (after filter) of two EDFAs are connected by connector technique. The stimulated emission is due to population inversion and population inversion is due to pump power. Fig 1.8, Fig 1.9 shows the bar chart analysis of amplified signal output power and ASE noise for single Forward pumping using single and multi wavelength sourrces.

TABLE II
RESULTS: SIGNAL POWER, NOISE FIGURE, GAIN AND ASE NOISE IN TWO EDFAS CONNECTED BY CONNECTOR AND SPLICE WITH MULTIPLE SOURCES (1520NM-1617NM)

Parameters	**Multiple Sources(1520nm – 1617nm) with 0.001W/nm, pump power=0.12W EDFA length= 10m**		
	With Connector	**With Splice**	**Remarks**
Gain (DB)	33.315	33.624	**Increases in Splice**
Noise Figure(DB)	5.8	5.8	Maintained
Signal power (W/nm)	Before connector 0.004	Before Splice 0.004	Maintained
	After connector 0.0038	After Splice 0.0039	**Decreases**
	After filter 0.0022	After filter 0.0024	**Increases in splice compared to connector**
ASE noise	Before connector 0.0002667	Before Splice 0.0002667	Maintained
	After connector 0.00024	After Splice 0.00024	Decreases both
	After filter 0.00013	After filter 0.00014	Decreases both

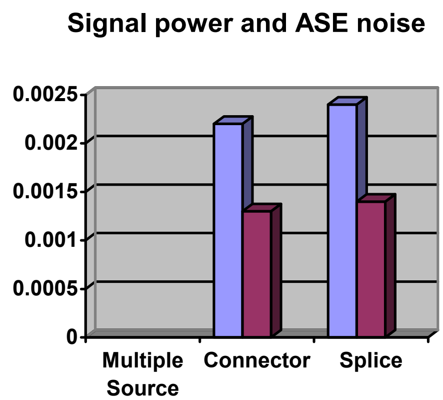

Fig 1.9. Output amplified Signal Power and ASE noise in multi wavelength sources of single Forward pumping with wavelength 980nm with the constant input signal power=0.001mw

VI. CONCLUSION AND FUTURE ASPECTS

In summarize, we have simulated the two EDFAs are connected by connector and splice model with single and multi wavelength sources using single pumping scheme of 980nm The results Gain, Signal power, noise figure and Output ASE noise were compared and analyzed with single (1550nm) and multiple sources of wavelength (1520nm – 1617nm). The connector gives the permanent connection and splice gives the temporary connection between the fibers. . The results compared with the conventional EDFA parameter values. In Connector technique the ASE noise reduced in multiple input sources and in single source the signal power equal in connector and splice technique. The analyzed model is applicable in Network reconfiguration and Multi-vendor networks and also addition of new services and wavelengths

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