Performance analysis of HG_EDFA and LN_EYCDFA

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***Abstract*—*The scope of this paper is to analyze the performance of HG_EDFA (High Gain Erbium Doped Fiber Amplifier) and LN_EYCDFA (Less ASE Noise erbium-ytterbium co-doped fiber amplifier) using single pumping with the wavelength of 980nm by the various parameters like Gain, forward output signal power and forward and backward ASE (Amplified spontaneous Emission) noise power. This Paper describes the simulation models of HG_EDFA is connected with an input of (DMLaser1) direct modulated laser source and the performance was analyzed with the parameters were measured and the values are tabulated and plotted and compared with LN_EYCDFA. The simulation model consists of input source 1mw with wavelength (1550nm), pumping CW Laser source with wavelength 980nm and Filter. The resulting models were accurately represents Gain and optimized output signal power. Simulation results shows that by choosing careful fiber length 20m and pump power 1mw in single pumping gives ASE noise 0.0025mw in HG_EDFA and $12X10^{-14}$mw in LN_EYCDFA.*

Keywords*— *ASE noise power, Output signal power, HG_EDFA, CW Laser, Optical Fiber Communications, Single Pumping, wavelength and WDM.

I. 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 fiber acts as 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, HG_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 HG_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 HG_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 HG_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 HG_EDFA. An important issue is the selection of a proper pumping wavelength or a suitable pumping configuration. The pumping wavelength dependence of the amplification characteristics of the HG_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 HG_EDFA's

B. LN_EYCDFA:

This block models the operation of an erbium-ytterbium co-doped fiber amplifier (LN_EYCDFA) shown in Fig 1. The model supports component specifications at different levels of complexity, as well as a variety of pump and signal configurations. Physical LN_EYCDFA model uses the Forward-propagating optical signals are launched into the LN_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 LN_EYCDFA output is available at the output node, and includes any signals, pumps, and amplified spontaneous emission (ASE) that are exiting the amplifier. The LN_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 and ytterbium ion densities in each atomic level. In most LN_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

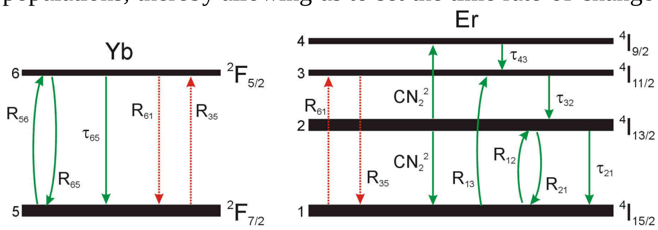

Fig.1: Erbium and ytterbium atomic manifolds

C. Signal power in an HG_EDFA

The output signal power is calculated as

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

Where G is the HG_EDFA (Amplifier) power gain and Pin is the input signal power. The most important feature of the HG_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 HG_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 HG_EDFA work in the C-band. Noise is the second most important characteristic of an optical amplifier.

C. ASE Noise:

The principle of HG_EDFA without any input an erbium ions decay and gets amplified gives the ASE noise shown in Fig.2. ASE noise is dominant in HG_EDFA.

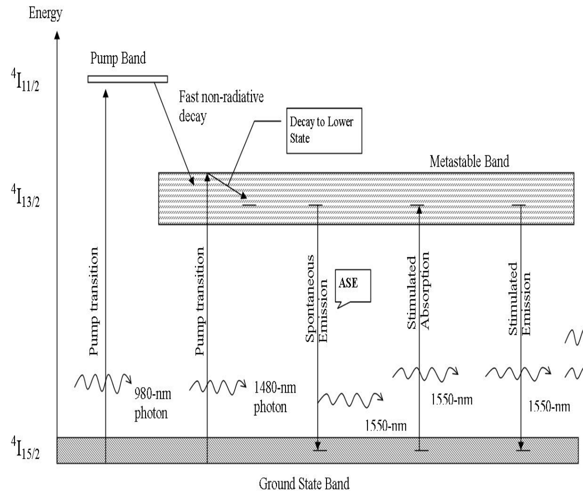

Fig.2: HG_EDFA Structure

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.

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, gives the performance analysis HG_EDFA and LN_EYCDFA with various parameters amplified forward signal output power, Gain, noise figure and forward and backward ASE noise from the simulation model of HG_EDFA connected with single pumping of 980nm compared with LN_EYCDFA connected with single pumping of 980nm separately with length 20m have been simulated with DMLaser1 block and a high performance approach is presented that has not been used in this manner before such design.

A. Applied Methodology

The applied methodology is based on single pumping approach in both HG_EDFA and LN_EYCDFA. 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 (Forward output signal power, Gain, and forward and backward ASE noise) values.

B. Proposed Work

The Proposed work uses DMLaser1 with an input of 1mw source produced the coherence output follows the model given in simulation model HG_EDFA is the dominant optical fiber amplifier gives maximum gain and amplified signal output compared with LN_EYCDFA.

Recently, lots of problems in bidirectional HG_EDFAs were investigated, and various structure schemes of the HG_EDFA were reported to overcome the problems, such as back reflections [3]. An automatic gain control (AGC) function for bidirectional HG_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 HG_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]. Filter here is to remove the unwanted wavelengths.

IV. MODEL SIMULATION

Simulation model consists of PRBS Pattern Generator, Electrical Signal Generator, optical combiner, non linear fiber, HG_EDFA (HG_Erbium doped Fiber Amplifier) and optical filter.

PRBS Pattern Generator: Produces a maximal length pseudo-random binary sequence and Electrical Signal Generator converts an input binary signal into an output electrical signal. The output signal may be specified as either voltage or current. The user parameters are used to configure the electrical signal output. An electrical signal output enables the DMLaser1 to generate the optical signal and focused into the nonlinear fiber and gets amplified by the HG_EDFA or LN_EYCDFA and again sends it to the nonlinear fiber and the frequency restricted by an optical filter.

The simulation model, HG_EDFA connected with single backward pumping (980nm) shown in Fig 3 and Fig 4 shows the LN_ EYCDFA connected with single backward pumping. The parameters Output amplified signal power, noise figure , Gain and ASE noise has been measured with pump power 0.12W and HG_EDFA Length 10m from the simulation model and that has been tabulated and analyzed.

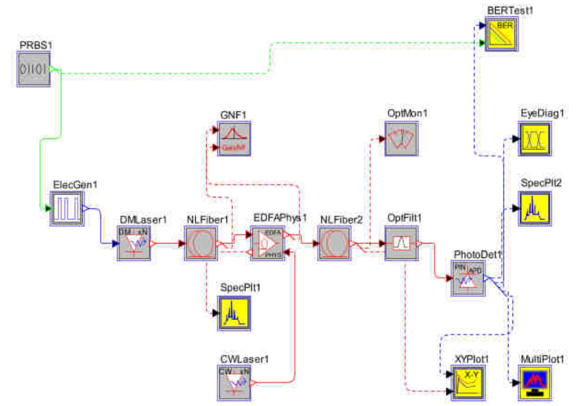

Fig.3: Simulated model of HG_EDFA using single backward Pumping scheme

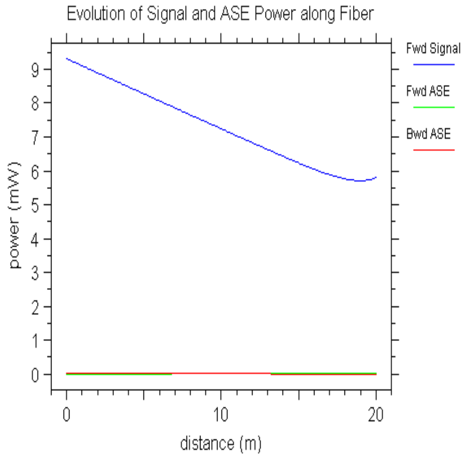

Fig.5: Forward Signal and ASE noise characteristics of HG_EDFA using single backward Pumping scheme

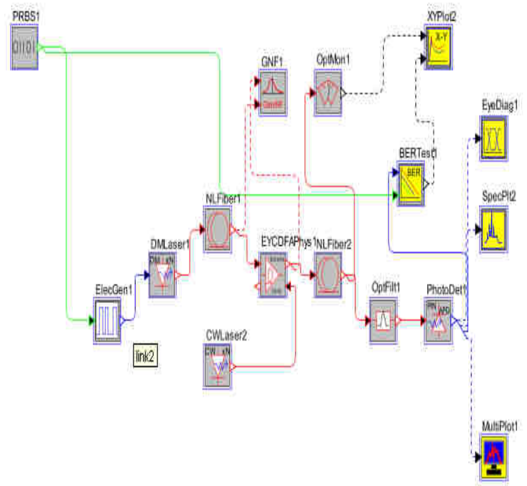

Fig.4: Simulated model of LN_EYCDFA using single backward Pumping scheme

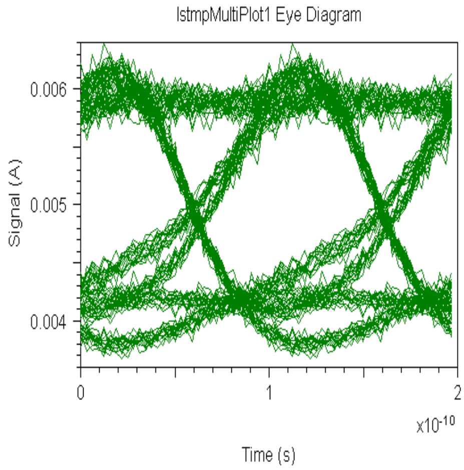

Fig.6: Eye diagram of HG_EDFA using single backward Pumping scheme

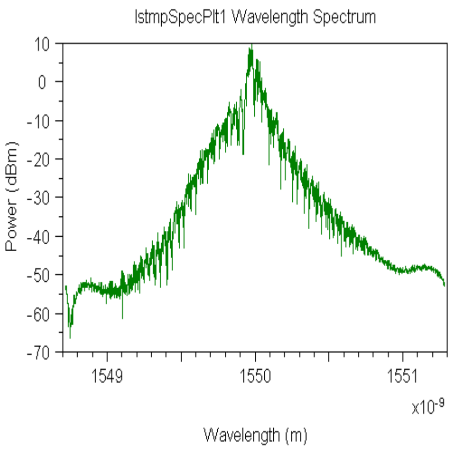

Fig.7: Forward Signal spectrum characteristics of HG_EDFA using single backward Pumping scheme

The gain spectrum of HG_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.

V. RESULTS & DISCUSSIONS

The output of HG_EDFA has been taken and shown directly the signal output, ASE noise, and forward signal spectrum and eye pattern of HG_EDFA in Fig 5, Fig.6 and Fig.7. The average atomic level densities of two levels N_1 and N_2 shown with respect to distance of 20m in Fig 8.

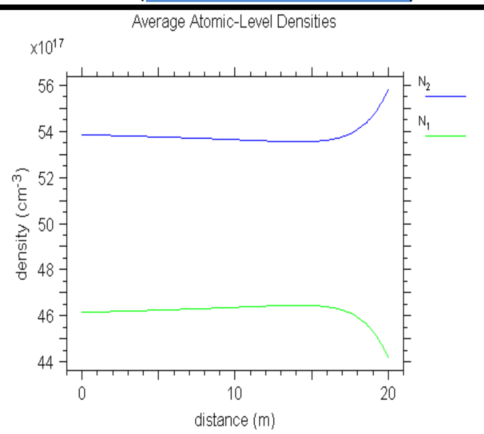

Fig.8: Average Atomic level densities of HG_EDFA using single backward Pumping scheme

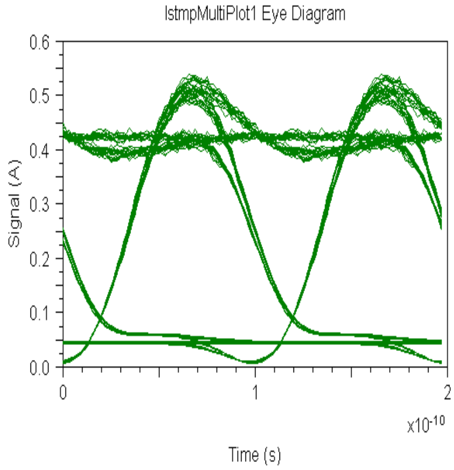

Fig 9. Eye pattern of LN_EYCDFA using single backward Pumping scheme

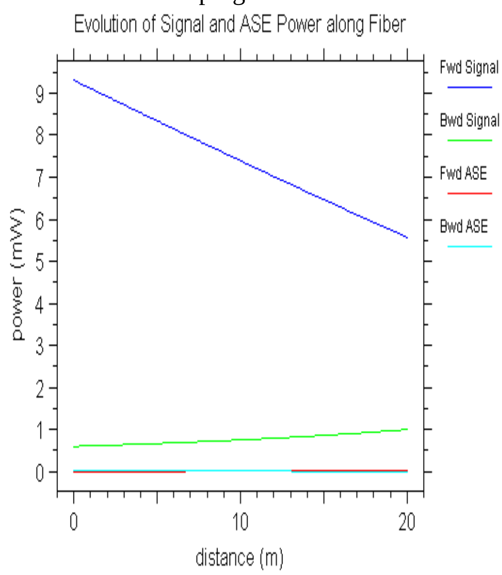

Fig.10: Forward Signal and ASE noise characteristics of LN_EYCDFA using single backward Pumping scheme

Fig.10 shows the ASE noise and signal power characteristics of LN_EYCDFA

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

TABLE I
RESULTS: PERFORMANCE ANALYSIS OF HG_EDFA & LN_EYCDFA WITH DMLASER1 POWER 1mW, HG_EDFA LENGTH 20M AND PUMP POWER =1mW

Parameters	**Pump power=1mw HG_EDFA length= 20m**		
	HG_EDFA	**LN_EYCDFA**	**Remarks**
Gain (DB)	**-2.05**	-2.22	**High**
Forward Signal power(mw)	9	9	Maintained
Backward signal power(mw)	**0**	1	**Decreases in HG_EDFA**
ASE noise (Forward)mw	0.0025	**$27X10^{-17}$**	**Decreases in LN_EYCDFA**
ASE noise (Backward) mw	**0**	$9X10^{-17}$	**Decreases**
Eye Opening	0.0025	**0.3**	**Less ISI in LN_EYCDFA**

Table I shows the simulated values are Gain, amplified output signal power, ASE noise at fiber ends compared using single pumping technique tabulated, for HG_EDFAs length=20m, pump power=1mw and signal input power=1mw compared with LN_EYCDFA.

Fig 6 shows the Eye diagram characteristics of HG_EDFA and Fig. 7 shows the Signal power Vs ASE Noise Characteristics of HG_EDFA. Fig. 8 shows the Average atomic level density of HG_EDFA and Fig. 9 shows the Eye diagram of LN_ EYCDFA.

VI. CONCLUSION AND FUTURE ASPECTS

In summarize, simulated the HG_EDFA and LN_EYCDFA separately using single backward pumping scheme of 980nm. The results Gain and ASE noise were compared and analyzed with single (1550nm). Advancements in HG_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 HG_EDFA utilizing single pumping technique was successfully simulated. HG_EDFA gives maximum gain compared to LN_EYCDFA but LN_EYCDFA gives less ASE noise than HG_EDFA. HG_EDFA is the best for communication with broad band services with long haul applications. The analyzed model is applicable in Network reconfiguration and Multi-vendor networks and also addition of new services and wavelengths.

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