PERFORMANCE EVALUATION OF HYBRID OPTICAL AMPLIFIER IN FIBER OPTICAL COMMUNICATION SYSTEM

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Abstract

The advancement in Optical communication network for its enormous capacity and low transmission loss, leads to development of powerful optical amplifiers. As the demand for higher transmission capacity in WDM (Wavelength Division Multiplexed) systems increases, the channel speed, channel number, and spectral efficiency need to be upgraded. The Gain of Erbium doped fiber amplifier (EDFA) and Raman amplifier is combined to obtain the net gain i.e. 20-25 dB over a bandwidth of 1.5 THZ.

In this paper, we review that the hybrid optical amplifiers are designed to enhance the bandwidth, to maximize the span length, and to achieve better gain.

Keywords- WDM, EDFA, RAMAN, SMF, DCF

I. INTRODUCTION

Amplification is done via three types of optical amplifiers: Erbium doped fiber amplifier (EDFA), Raman Amplifier and Semiconductor Optical Amplifier (SOA).

An EDFA in combination with a distributed Raman amplifier (DRA) to achieve a higher gain with lower noise figure or a wider amplification band is to use. Thus, a hybrid C + L-band EDFA/RFA is a promising technology for WDM systems, (ii) by adjusting the pump powers and pump wavelengths the gain spectrum of DRA can be vary. By using this property the amplification bandwidth of EDFA is increased and (iii) DRA suppress the nonlinear effects produced by SOA. SOA benefits include the ability to facilitate wavelength conversion and all optical regeneration and distributed Raman amplifiers (DRA) type of amplifiers requires powerful pumping sources as it provides broad amplification spectrum, less amplified signal distortions, even negative noise figure values [1].

Hee Sang Chung et al. [2] proposed a low-noise band EDFA with a dispersion-compensating Raman amplifier. With optimized pre-stage and 1500 nm Raman-pump laser diodes, the proposed EDFA achieved an internal noise figure of less than 4.5 dB over a 33 nm flat gain bandwidth within 0.5 dB at 2 dBm of large signal input power.

J. X. Cai et al. [3] proposed a capacity improvements using wide optical bandwidth amplification provided by C + L EDFAs and Hybrid Raman EDFAs. Both designs operated at or close to the optimal non-linear performance across the band, use variable spectral efficiencies and near Nyquist spectral shaping.

Simranjit Singh et al. [4] compared the different dispersion compensation techniques. They observed that RAMAN-EDFA as post power compensation method provides least bit error rate and high output power.

In this paper, we have proposed the hybrid optical amplifier (RAMAN-EDFA).The paper is organized into four sections. In Section 2, EDFA and RAMAN amplifiers are discussed. In Section 3, the optical simulation setup and comparison results have been reported and finally in section 4, conclusions are made.

II. Erbium Doped Fibre Amplifier

EDFA, an amplifier has the ability to produce significant gain under low pumping power. [5]. By using semiconductor lasers operating near 0.98 μm and 1.48-μm wavelengths efficient EDFA pumping is possible [1]. A wavelength selective coupler is used to mix the high powered beam of light with the input signal. The input signal and the excitation light must be at significantly different wavelengths. The isolator is placed at the output to prevent reflections returning from the attached fibre as shown in fig. 1.

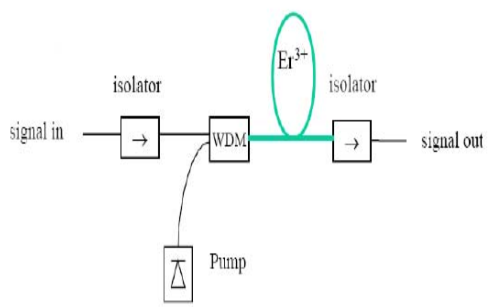


Fig. 1. Block Diagram of an EDFA

The features of the EDFA Gain clamping and Gain flattening plus its wideband amplification capability make it a common amplifier of choice in optical communication systems. The device parameters such as erbium ion concentration, amplifier length, core radius, and pump power effects the gain of an EDFA [1].

III. Raman Amplifier

Similarly, Raman fibre amplifiers (RFA) used in conjunction with EDFA's to form hybrid amplifiers, by raising channel speed and spectral efficiency the system capacity needs to be upgraded [6],[9-10].In Stimulated Raman scattering the energy is transferred from the pump light to the signal via excitation of vibrational modes in the constituent material. This gain is accompanied by amplified spontaneous emission.

IV. Gain of EDFA and RAMAN

The EDFA is modeled as three level system [7]. The gain is calculated as

$G_{EDFA}=G_{max}(L,\lambda_P,\lambda_S)=\exp L\,\frac{r_p(\lambda_p)-r(\lambda_s)}{1+r_p(\lambda_p)}$ ……...(1)

Where the dependence of G_{max} on λ_p (pump wavelength) and λ_s (signal wavelength), appear explicitly in the cross-section ratios $r_p = \sigma_{pa}/\sigma_{pe}$ (pump absorption/pump emission), $r = \sigma_{sa}/\sigma_{se}$ (signal absorption/signal emission).The parameter L varies with signal wavelength.

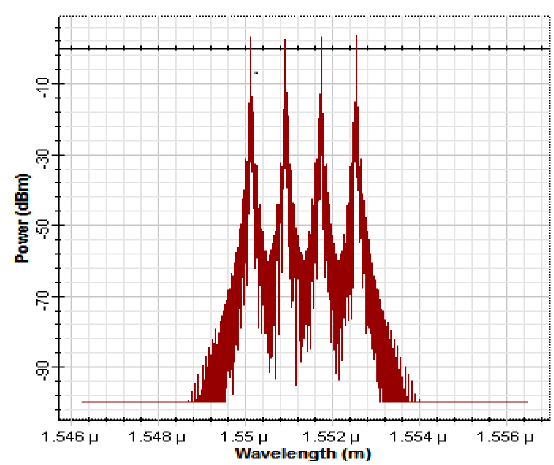
In a Raman amplifier the power spectrum of the optical signal is affected by Raman pumping (only counter propagation is considered here), Raman amplified spontaneous emission (ASE) noise and Rayleigh back- scattering. The pump power does not remain constant along the Raman fibre length. When these effects are included, the Raman amplification process is governed by the set of two coupled equations described in [8]. Also the signal gain is given as

$G_{RAMAN}=G(z)=\frac{P_s(z)}{P_s(0)}=\exp\left(g_R\int_0^z P_p(z)dz-\alpha_s z\right)$ …………………………………….(2)

Where P_p and P_s are the pump and signal power, respectively. On the other hand, z is the longitudinal position along the fiber and α_s is the Rayleigh scattering coefficient.

For HOAs the total Gain is the addition of the individual gains of the cascaded amplifiers. Then the total gain of the proposed RAMAN-EDFA (G_{RE}) is given as

$G_{RE}=G_{RAMAN}+G_{EDFA}$ ……………………………………..(3)



Similarly the Gain for the RAMAN-SOA and EDFA-SOA is calculated.

V. SIMULATION SETUP

Each transmitter section consist of data source, electrical driver, and Continuous Wave (CW) laser source and mach-zehnder modulator. The data source is NRZ/RZ format at 10 Gb/s as shown in fig. 2. The continuous wave laser source generates the laser beam at 1550 nm. The input data source modulates at laser beam using a mach-zehnder modulator. The output of modulator is fed to the optical link consist of single mode fibre, dispersion compensated fibre and RAMAN-EDFA hybrid optical amplifier.

A WDM Transmitter has been used with center frequency 1552.52 nm, frequency spacing 100 GHz and with different input power - 20dBm, -10dBm, 0dBm and 10dBm. The input signal and output signal can be visualized by attaching an Optical Spectrum Analyser to the WDM transmitter.

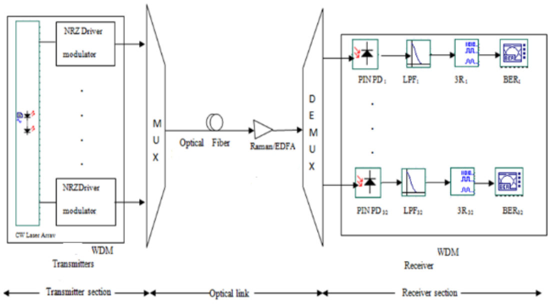


Fig. 2. Simulation setup

The input signal and output signal is as follows in fig. 3(a) and 3(b).

Fig. 3(a). Input Signal of WDM systems

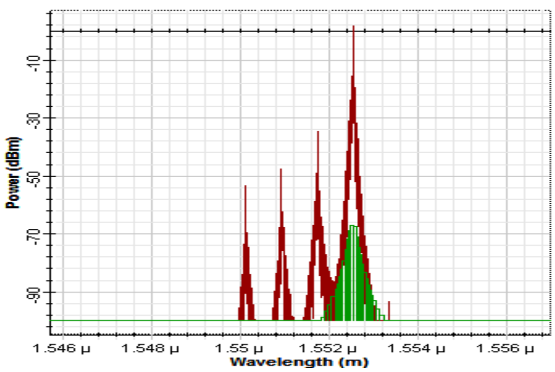


Fig. 2(b). Output signal of WDM System

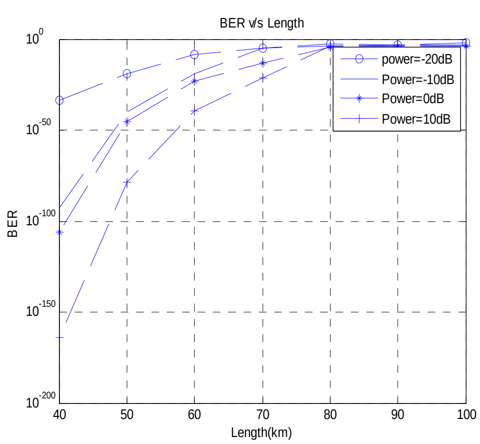


Fig. 4. BER vs. Length for different input power

From fig. 4 it is observed that the BER increases as distance increases for different input power. The variation in BER of hybrid optical amplifier i.e. RAMAN-EDFA for -20dB, -10dB, 0dB and 10dB is $2.8*10^{-4}$ to $1.0*10^{-164}$, $1.4*10^{-4}$ to $7.0*10^{-107}$, $3.9*10^{-4}$ to $2.8*10^{-93}$ and $1.2*10^{-2}$ to $4*10^{-34}$.

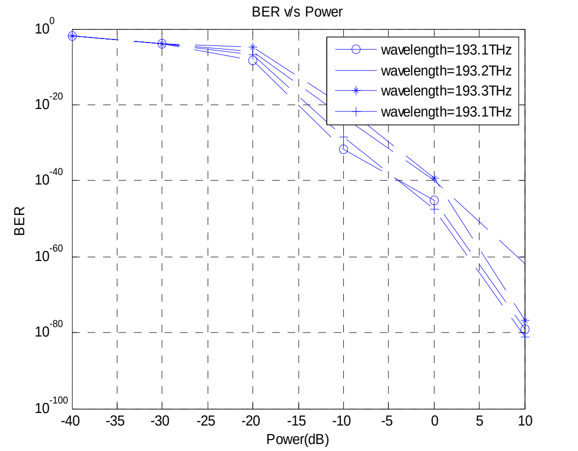


Fig. 5. BER vs. Input Power for different wavelengths

The variation of the BER against Power for the four channels is shown in fig. 5. It is observed that BER decreases as Input power increases. For all the wavelengths for less power there is no variation of BER.

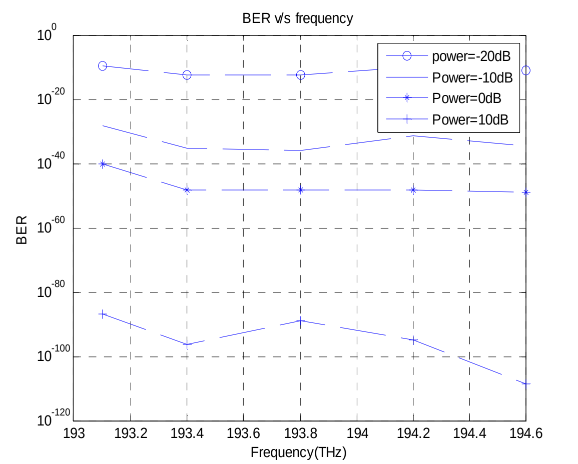


Fig. 6. BER vs. Frequency for sixteen channels

For sixteen channels consisting of wavelengths from 193.1-194.6. The graph is plotted b/w BER and frequency for different input power as shown in fig. 6. The BER is flat for the frequency range of 193.4-194.6 for input power of 0 dB.

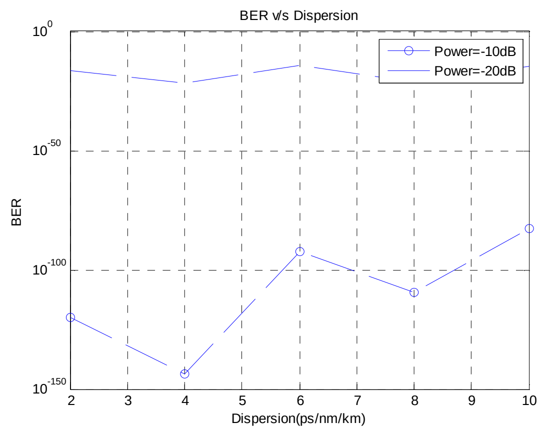


Fig. 7. BER vs. Dispersion for different input power

Fig. 7 shows the graphical representation of BER as a function of dispersion. It is clear from the figure that as the dispersion varied from 2 to 10 ps/nm/km the BER increase for -10 dB it varies from 10^{-120} to 10^{-83} and for -20dB it varies from 10^{-17} to 10^{-22}.

For a span length of single mode fibre (SMF) is 120 km with dispersion 16 ps/nm/km and the length of dispersion compensating fiber (DCF) is 20 km with dispersion -80 ps/nm/km.

The equation for determining the length of compensating SMF was found in Aggarwal [1] as:

$$L_2 = -\left(\frac{D_1}{D_2}\right) * L_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where L_1 and L_2 are lengths of SMF and DCF respectively and D_1 and D_2 are the dispersion parameters for SMF and DCF respectively.

The Mach-zehnder modulator is used. The RAMAN amplifier parameters are length 25 km and pump wavelength 1480 nm with pump power 800 mW. The EDFA parameters are Gain 10 dB and noise figure 4 dB.

Table 1. Different cases for variation of lengths for DCF and SMF determined from eq. (1)

Case	DCF(Length (km))	SMF (Length(km))
1	4	24
2	6	36
3	8	48
4	10	60
5	12	72
6	14	84
7	16	96
8	18	108
9	20	120

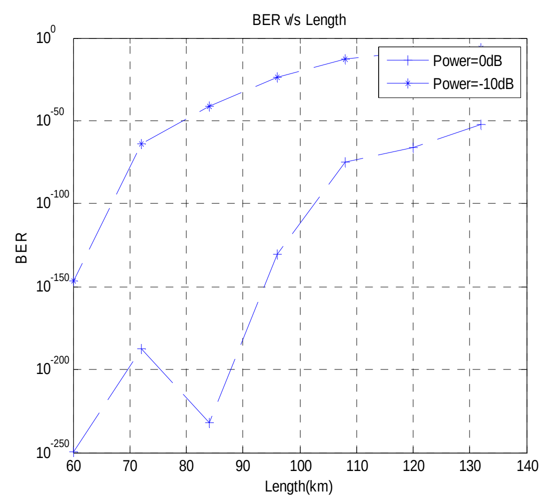


Fig. 8. BER vs. Length for different cases as indicated in Table 1.

Fig. 8 shows that the BER as a function of Length is plotted for input power of 0 dB and 10 dB. It is observed that using DCF the distance can be increased. The BER for 0 dB varies from $8*10^{-250}$ to $1.2*10^{-53}$ and for 10 dB varies from $4.5*10^{-147}$ to $4.1*10^{-7}$.

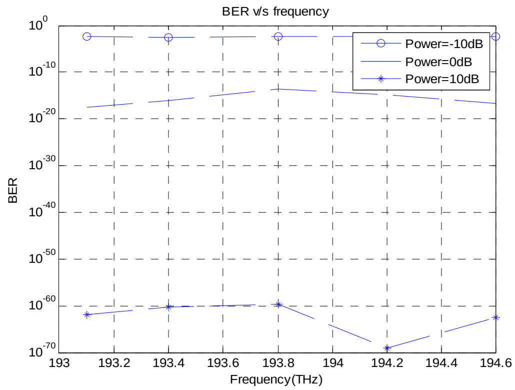


Fig. 9. BER vs. Frequency for sixteen channels using DCF

It is observed from the fig. 9 that the BER for RAMAN-EDFA using DCF for -10 dB is flat. The BER for 0 dB varies from 10^{-19} to 10^{-18} and for 10 dB varies from 10^{-63} to 10^{-67}.

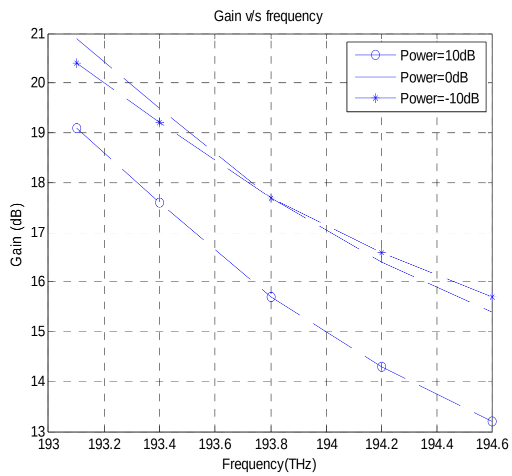


Fig. 10. Gain spectra of HOA for different input power

Fig. 10 shows that as we increase the input power, the gain variation increases over a bandwidth of 1.5 THz.

CONCLUSION

The performance of the hybrid optical amplifier using RAMAN-EDFA for WDM system with frequency spacing of 100 GHz is evaluated. The BER is obtained for different frequency range and also for different length of fibre. The Gain of the hybrid optical amplifier is obtained for the different frequencies. As the net Gain is the sum of individual gain of the optical amplifier. The work can be extended further for the different frequency spacing and data rate.

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