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Optimization of DWDM system using Hybrid Optical Amplifier with Ultra small Channel Spacing

Lokesh Lodha*[1], Anil Agarwal[2]

[1,2] *Associate Professor, Department of Electronics & Communication Engineering, Jaipur National University, Jaipur, Rajasthan, India*
[1]*lk_jnu10@yahoo.com*, [2] *aniljecrc11@yahoo.com*

Abstract— **Optical fiber has the quality of low cost and minimum loss for the transmission of optical signals. This paper presented a hybrid amplifier configuration is implemented with an optical fiber RAMAN amplifier and an EDFA amplifier for the channels for 160 DWDM systems at 10 Gbps & 25 GHz frequency spacing. By this, a level gain of >12.5 dB is appeared between the frequencies 187 THz to 190.975 THz with variation in gain is <4.57 dB for 1 mW input signal power. The power obtained at output for the input of 1mW power is the utmost value (>8.86dBm) for FRA–EDFA hybrid optical amplifier at ultra small channel spacing and without applying any gain-flattening technique and receiver filters. The OSNR received for 1 mW input power is ranging from 25.4 dB to 27.2 dB. OSNR value is increases with the increase the input power value.**

Keywords: - EDFA, FRA, DWDM, Gain, Output Power, OSNR

1. INTRODUCTION

The fast expansion of optical communication networks has created a requirement to increase the transmission capability of these networks. One of the most popular techniques is DWDM i.e. dense wavelength division multiplexing. For DWDM channel system, wideband fiber amplifiers plays a vital role in optical networks [1]. The advancements and development in optical fiber amplifiers allowed highly increased in the capacity of optical propagation systems, with the reduced cost of the system by using repeater less transmission. Which amplifies the transmitted optical signal directly without conversion them into electric forms [2]. In long distance optical communication, optical repeaters, preamplifiers and erbium doped fiber amplifiers (EDFAs) pumped Laser diode will contribute major part as power boosters [3]. Multi-pump Raman amplification with EDFA have been a desired technique for optimizing the gain profile of broadband hybrid amplifiers used for long-haul optical fiber transmission systems. The hybrid amplifiers with optimized Raman pump wavelengths and powers are used for broadband amplifiers [4]. So, in this paper, work on performance evaluation of hybrid optical amplifiers for larger gain with a minimum gain variation and improved transmission distance for DWDM communication systems is highlighted. In literature review, various gain flattening techniques using number of amplifiers with single or multiple pumping have been projected to minimize the gain variation over the frequency region. Simranjit singh et al. [5] presented a HOA model using two stages DRA-EDFA DWDM system to minimize the gain variation without using any gain flattening technique. They explained that the total amplifier gain (G Hybrid) is the addition of the individual gains of the cascaded amplifiers gain. Hari et al. [6] investigated the various types of optical amplifiers for fewer number of channels having high wavelength spacing using eye pattern, BER and Q factor and observed optimized distance of transmission for transmitting the signal. Lee et al. [7] presented the hybrid amplifier for dispersion compensating with one pump source for recycling residual Raman pump to increase the efficiency of power conversion and achieve gain and effective gain bandwidth. Masuda et al. [8] proposed gain flattened and a wide band discrete HOA for long-distance WDM optical transmission systems. Cheng et al. [9] demonstrated a bismuth-based erbium-doped fiber amplifier (Bi-EDFA) and it works in both the L- band and C-band wavelength regions using a midway broadband fiber Bragg grating sensor to lower the noise figure and to improve flat gain characteristics. Optical fiber is a better medium for transmission in long haul applications, but there are some problems regarding optical fibers, which degrade the efficiency of the fiber optic system. Therefore, the entire above researchers use different setups with variable

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parameters to provide high flat gain, less noise figure, less system cost and large gain bandwidth for multiple channels. But some of them used large channel spacing, less number of channels, costly components in their systems. B.A. Hamida et al. [10] discussed about the cascading of double-pass amplifiers connected in series and parallel configuration, and realized a wide-band operation covering large wavelength region. M. L. Meena et.al. [11] research described the performance related to long-haul optical transmission system having eight channels DWDM with DCF and chirped FBG techniques. EDFA amplifier is used to reduce the attenuation and dispersion phenomena to overcome these problems, there are evaluated the various HOAs for DWDM system at less wavelength spacing and greater bit rate. In this paper, authors investigated an RAMAN-EDFA model to achieve better gain flatness with improved distance by avoiding the use of any gain flattening components like fiber grating and gain equalizers etc. Singh K et. al. [12] studied effect on gain of FRA due to variations of different types of pumping parameters such as pump wavelength and pumps power by using dual and triple pumping. After the introduction, simulation setup and parameters of Raman-EDFA are expressed in the section II of this paper. Section III covers the outcomes of the experimental setup and simulation result. Lastly conclusion discussed in the Section IV of this paper.

2. SIMULATION SETUP

In this paper, Fig. 1 shows the proposed simulation setup, 160 channels were used for transmitters and receiver model having channel spacing of 25GHz and data rate of 10 Gbps. A Pseudo Random Binary Sequence (PRBS) generator generates the input signals according to order operation mode. Input signal is modulated using NRZ pulse generator i.e. electrical driver and Mach Zehnder modulator is used for modulation of input signal. Modulated signals are sending to the channels through which these modulated signals are transmitted over SMF type of optical fiber of 100 km transmission distance. After the multiplexer, modulated signal is analyzed using optical spectrum analyzer and it is used at receiver side to observe the power. The logical input signal is converted by using NRZ pulse generator into equivalent Gaussian electrical signal. The required 160 laser beams are generated by using CW laser sources, which helps to cover the L-band at the frequency range from 187–190.975 THz with the wavelength spacing of 25GHz in the system.

The simulation setup of Hybrid Optical Amplifiers using compound component at 1, 3 and 5 mW input signal power are shown in Fig. 1. This optical signal is transmitted through the channel and measured output power, gain and OSNR over frequency region considering its nonlinearities individually. A DCF is used to compensate the dispersion over a fiber span. Optical spectrum analyzer, dual port WDM analyzer and BER analyzer are used to measure the signal power, spectrum and gain at different positions. A WDM de-multiplexer is used to receive output of all the channels individually and feed to the photo sensor to recover in equivalent actual signal. The modulated signal is demodulated by using a PIN diode as photo sensor at receiver end. The setup is simulated repeatedly for measuring the strength of signal by using different values of input signal power.

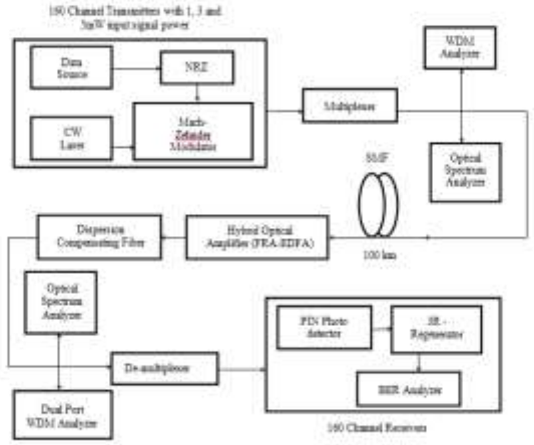

Fig. 1 Block Diagram of Simulation Setup for Proposed Scheme

Since different elements have different types of operational specifications and parameters. The DCF and SMF type optical fibers are used to dispersion compensation and transmit the optical signals and respectively. Its different types of parameters are shown in Table 1.

Table 1 Various Parameters for DCF and SMF Optical fiber

Parameters	DCF	SMF
Reference wavelength	1550 nm	1550 nm
SMF length	17 km	100 km

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PMD coefficient	0.1 ps/km$^{1/2}$	0.1 ps/km$^{1/2}$
Dispersion	-90 ps/nm/km	16 ps/nm/km
Nonlinear refractive index (n2)	2.5e-^{020} m^2/w	2.5e-^{020} m^2/w
Attenuation	0.5 dB/km	0.2 dB/km

The flat gain EDF amplifier is connected to boost the optical signal. Its different types of parameters are defined in Table II.

Mode of Operation	**Gain control**
Gain shape	Flat
Noise figure	4 dB
Small signal gain (Fixed)	25 dB

Table 2 Parameters for EDFA

The FRA amplifier is also connected to fulfill the requirement of enhanced output power. Table III shows the different parameters-

Table 3 Parameters for FRA Amplifier

Fiber length of FRA	22 km
Attenuation	0.2 dB/km
Operating Temperature	300 K
Frequency of Pumping	207 THz, 201THz
Power of pumping	650mW, 250mW

The PIN diode is used at the receiver side as photo sensor having responsivity of the order of0.875 A/W along with dark current of 0.1 nA.

3. RESULT

The different hybrid optical amplifier configurations have been compared for 160 channels at 10 Gbps DWDM system for 1, 3 and 5 mW input signal power in term of received maximum output power (dBm) and gain (dB) with its input power (dBm) and OSNR (dB) at all over frequency region.

The results for the presence of nonlinearities for gain vs. frequency region are given in the Fig. 2. It is found that at 1mW input power gain increases from 12.49 dB to17.06 dB with gain variation of 4.57 dB. Also, for 3mW and 5mW input powers gain enhanced from 10.66 dB to 15.46 dB and 9.57 dB to 14.41 dB with variations in gain 4.8 dB and 4.84 dB respectively.

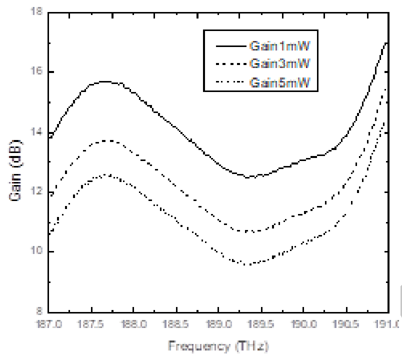

Figure 2 Diagram Showing Gain at 1, 3 and 5mW Input Power

This hybrid optical amplifier amplifies the power received at output as increased the input power, which is mentioned in Fig. 3. However, the variation in output is also higher with increasing the input power. The variations in output power after HOA are 8.86 dBm to 13.62 dBm for 1 mW, 11.82 dBm to 16.79 dBm for 3 mW, 12.98 dBm to 17.99 dBm for 5 mW input power received respectively. For 1 mW input power, output power variation is 4.76 dBm which is very small in comparison to other input powers.

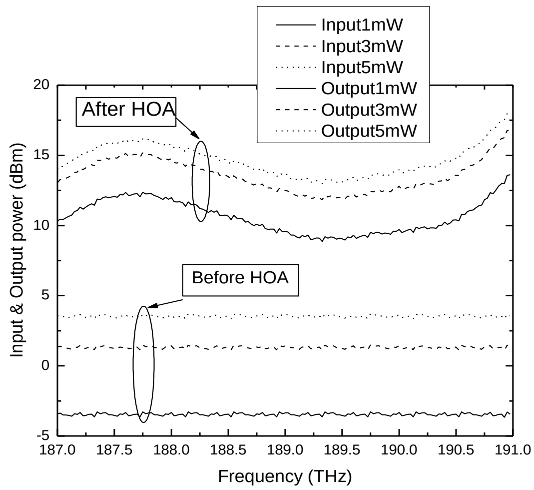

Figure 3 Diagram Showing Input & Output Power at 1, 3 and 5mW Input Power

Fig. 4. Illustrate the variation regarding to OSNR as a function of frequency. In this, at 1 mW input power OSNR received from 25.4 dB to 27.2 dB. For higher input power, value of OSNR is also increases.

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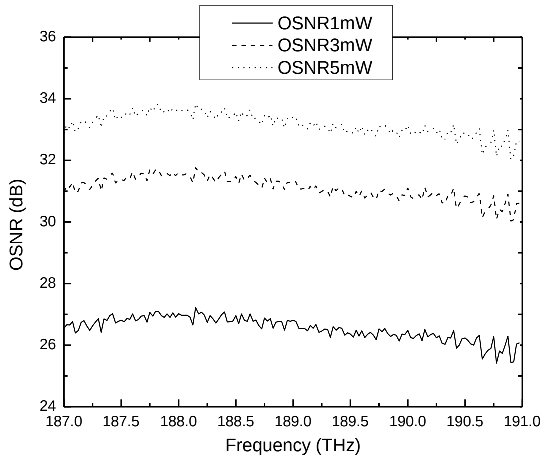

Figure 4 Diagram Showing OSNR at 1, 3 and 5mW Input Power

After comparing all the results it was found that proposed HOA scheme gives the better results for 1 mW input power from the others.

4. CONCLUSION

The hybrid optical amplifiers for 160 × 10 Gbps at 25 GHz frequency spacing models were effectively designed and implemented with the help of software Optisystem. The main motivation was to optimize the optical amplifier for various input signal power and observe the effect due to nonlinearities. The performance and functioning of hybrid optical amplifier was calculated based on the gain received, output power and OSNR. The software simulation results shows that FRA-EDFA with 1 mW input signal power performed better than other higher input powers.

In conclusion, this proposed FRA-EDFA model has provide a level gain of >12.5 dB for the frequency range from 187 THz to 190.975 THz with the variation in gain of < 4.57 dB for 1 mW input power. The obtained output power is the largest parameter (>8.86 dBm) for applying 1-mW input power. In addition, got the variation of less than 4.76 dBm using FRA–EDFA hybrid optical amplifier with minimized channel spacing without deploying any gain flattening techniques. Above 1mW input power, more variation in output power and gain after HOA can be appeared. Therefore, this proposed model is most suited for 1 mW input power.

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