Performance Optimization of Single & Hybrid Optical Amplifiers for 160 × 10 Gbps DWDM System

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Abstract: *In this article, different single and hybrid optical amplifier configurations are designed with Er-Yb co-doped fiber and FRA amplifiers for 160 channel DWDM systems at 10 Gbps & 0.2 nm wavelength spacing. These setups are transmitted and calculated over wavelength ranges from 1548 nm to 1580 nm. The parameters of different single and hybrid amplifiers are calculated in terms of gain, output power, BER, eye height and Q factor. By using these setups, (Er-Yb + Raman) shows finer results than other optical amplifiers. By this, a uniform gain of (>20.50 dB) is acquired over the wavelength region from 1548 nm to 1580 nm with a gain discrepancy of (<4.76 dB) for 1 mW input signal power. The output power secured is also the excessive value (>22.34 dBm) for (Er-Yb + Raman) hybrid amplifier at narrow wavelength spacing without applying any kind of gain-flattening methods. It also provides the least BER (-22.86), large Q factor (6.61) and good eye height (0.0291).*

Keywords: FRA, Er-Yb co-doped fiber, DWDM, Gain, Output Power, BER, Eye Height, Q factor.

1. INTRODUCTION

Optical communication is used to fulfil the deficiency of large data transmission within least amount of time using fiber cables as the medium. In this context, various methodologies are introduced to increase data transmission capability by expanding the channels in the WDM system. To find the appropriate model the problems, numerous wideband optical amplifiers are configured with the DWDM systems and have been observed their performance [1]. A new scheme is suggested by using different types of co-doped fiber amplifiers as a gain medium in the C-band [2]. Authors used two stages of bismuth-based erbium-doped fiber amplifier (Bi-EDFA). Which can produce the outcomes for both the L and C-bands with a broadband fiber Bragg grating to avoid the gain saturation, reduce the noise figure and flatten the whole gain spectrum [3]? So, the goal of this work is to perform data transmission for longer distance with improved gain and with minimum gain variation by using a different kind of single and hybrid optical amplifiers for DWDM communication systems. In the literature review, various techniques using different optical amplifiers with single or multiple pumping have been proposed to increase the transmission distance over the bandwidth region.

Authors experimentally analyze the functioning for different types of more efficient Raman/EDFA hybrid amplifier and single pump using DCF to analysis noise figure; SBS induced penalty and gain [4]. The different types of hybrid optical amplifier models are proposed and evaluated for 160 channels DWDM optical system to increase the gain for the wideband region [5]. Michael et al. [6] investigated the various parameters like cost of the system, capacity of the system, flat gain; higher bit error rate, greater bandwidth, least cross-talk, low distortion and high SNR etc. This paper explores some methods to improve overall performance such as wavelength multiplexing, gain flattening filter and use of EDFA's improved output power. Simranjit Singh et al. [7] presented an optical amplifier which works well for gain-flattened L-band region. They observed two-stage hybrid configuration comprises by DRA-EDFA for flat output power spectrum at 3mW for all input channels without using any gain flattening techniques. This paper discussed an optical amplifier operates in L and C- band using two-stage hybrid configuration comprises by DRA-EDFA for flat output power spectrum at 3mW for all input channels without using any gain flattening techniques. This paper discussed an optical amplifier operates in L and C- band using two-stage of enhanced Zr-EDF in dual-pass configuration as gain medium having the length of 3.5m [8]. Hafiz et al. [9] investigated various hybrid optical amplifiers for 100 × 10 Gbps dense wavelength division multiplexed (DWDM) system with wavelength spacing of 0.2 nm. The performance of EYDFA–Raman amplifier configurations are evaluated and compared to observe the gain, Q-factor and noise figure (NF) and for the wavelength range of 1540–1560 nm in C-band. Delvaux et al. [10] designed two HEDFA setups as power booster modules for repeater less data transmission for large distance communication at less bit rate. Meena et al. [11] limit the effect of pulse broadening with the help of two different kinds of dispersion recompense methodology. They found that the chirped FBG scheme performed above the satisfactory level then DCF due to low cost and small size.

The optimization method to improve the gain profile of hybrid amplifiers is achieved by introducing a multi-pump FRA stage [12]. Karamdeep Singh et al. [13] studied the behavior on the gain of FRA due to variation in various pumping parameters such as pump wavelength and power using double and triple pumping. Obaid et al. [14] discussed the hybrid EYDFA–Raman configuration. The study carried out for 100 × 10 Gb/s DWDM system and channels spaced at 0.2 nm without using any gain flattening filter. The higher and constant gain increases the probability of a practical approach of broadband long-haul DWDM applications. Lee et al. [15] experimentally described a dispersion-compensating Raman/EDFA hybrid amplifier. This amplifier increases its efficiency of power conversion by recycling the residual Raman pump and it gives better results. Hybrid amplifier proposed by the authors enhanced the effective gain bandwidth by boosting the signal gain up to 20nm and 15dB (for small signal) respectively. This result is better than the Raman-only amplifier. This study paper aims to establish a relation between the EDFA and SOA optical amplifiers in the WDM system based on the Q-factor and BER (bit error rate) for each wavelength [16]. Poda et al. [17] discussed technique which will raise the gain level from its previous value by considering the reduction in attenuation and loss of the signal strength of the optical amplifier. Optical fiber is a more desirable medium for transmission in long haul applications. Still, there are some problems also regarding optical fibers which degrade the efficiency of the fiber optic system. So, the entire above researchers use different setups with variable 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.

To overcome these types of problems, various single and hybrid amplifier configurations are investigated for DWDM system with a higher bit rate and reduced channel spacing. In this paper Er-Yb + Raman, Raman + Er-Yb, Raman and Er-Yb models are investigated to acquire better gain flattening with improved gain instead of using any gain flattening components like fiber brag grating and gain equalizers etc. After the introduction, simulation setup and parameters of SMF, Er-Yb Co-doped fiber and fiber Raman amplifier are further described in Section II. Section III covers the outcomes and observations of the experimental setups and conclusion defines in Section IV.

2. Simulation Setup

Simulation parameters are set for 160 channels optical communication system which operates at 10 Gbps data transmission rate with wavelength spacing of 0.2 nm. Initially, input sequences are produced by a Pseudo-Random Bit Sequence (PRBS) generator and shown as the data source in the schematic diagram. Input sequences are modulated by a Non-Return to Zero based pulse generator (electrical driver) and Mach Zehnder modulator. The modulated signals are fed to a multiplexer and then transmitted through the SMF optical fiber to transmission length of 100km. The NRZ based pulse generator transform the logical input data sequences into an equivalent Gaussian electrical signal. Wavelength span from 1548 nm to 1580 nm with 0.2 nm wavelength spacing is covered by generating 160 laser beams through a CW laser source.

The proposed simulation setup for different single and hybrid optical amplifier configurations are designed with Er-Yb co-doped fiber and fiber Raman amplifiers at 1 mW input signal power is shown in Fig. 1. These optical signals are transmitted and individually signal measured over wavelength region. BER analyzer, Optical spectrum analyzer and dual port WDM analyzer are connected to observe the signal power and gain spectrum at different points in transmission system. At the receiver, the transmitted signal is now converted back into its indigenous form by detecting through PIN diode. This procedure is repeatedly performed for estimating the signal strength for different single and hybrid optical amplifier configurations at 1 mW input signal power.

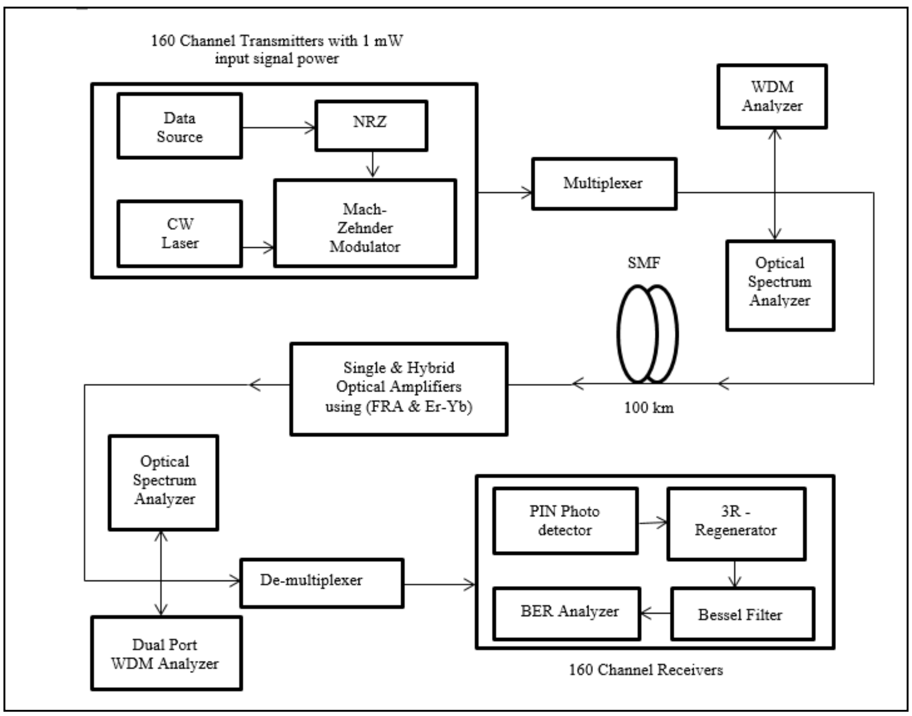

Figure 1. Schematic diagram for Proposed Simulation Setup

Different optical fiber medium has different operational parameters. Here, the SMF optical fiber is deployed as a transmission medium for the optical signals to a far distant receiver. Its required parameters are tabulated below in Table I.

Table 1 Parameters for SMF Optical Fiber

Parameters	SMF
Reference wavelength	1564 nm
SMF length	100 km

Attenuation	0.2 dB/km
Dispersion	16 ps/nm/km

The Er-Yb co-doped optical fiber is utilized to amplify the optical signal. Its necessary parameters are shown in Table II.

Table 2 Parameters for Er-Yb Co-doped Fiber

Parameters	**Er-Yb co-doped fiber**
Length	1 m
Doping radius	2 um
Core radius	2 um
Numerical Aperture	0.15
Er ion Density	5.14e+025
Yb ion Density	6.2e+026
Er Metastable Lifetime	10 ms
Yb Metastable Lifetime	1.5 ms
Pump Frequency	1056 nm
Pump Power	200 mW

Further, to amplify the output power, Fiber RAMAN amplifier is connected before the receiver. Different kind of parameters is shown in Table III for amplifier.

Table 3 Parameters for Raman Fiber Amplifier

Parameters	**Fiber RAMAN amplifier**
RAMAN fiber length	25 km
Attenuation	0.2 dB/km
Temperature	300 K
Pump Wavelength	1437.2 nm, 1464.5 nm
Pump power	650 mW, 250 mW

At the signal receiver side, the PIN photo detector is connected having the capability to pass dark current of 0.1 nA with a low pass Bessel filter and responsivity of 0.875 A/W.

3. Result

The different single and hybrid optical amplifier configurations have been compared for 160 × 10 Gbps DWDM system for 1 mW input signal power in terms of received maximum gain (dB), log of BER, output power (dBm), Q factor and eye height over wavelength ranges from 1548 nm to 1580 nm.

The results for the gain vs wavelength region are given in Figure 2. It is found that for (Er-Yb + Raman) hybrid amplifier, we receive maximum gain with minimum gain variation in the range from 20.50 dB to 25.26 dB with the gain variation of (< 4.76 dB). But for other hybrid and single optical amplifiers, the gain is very less with large gain variation. So the gain for other amplifier configurations (Raman + Er-Yb, Raman and Yb) are from 0.04 to 11.61 dB, -2.61 to 10.42 dB and -10.84 to 2.05 dB with gain variation of 11.57 dB, 13.03 dB and 12.89 dB respectively.

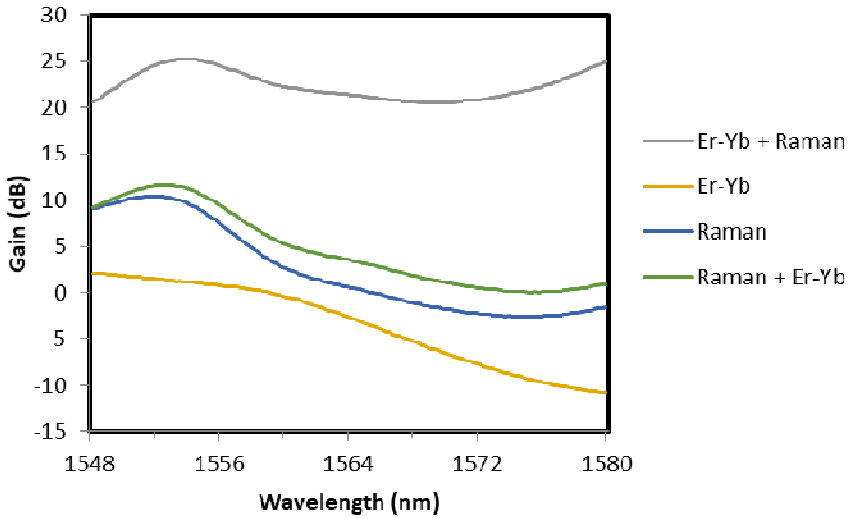

Figure 2 Diagram Showing Gain Variation for Different Single and Hybrid Optical Amplifiers at 1 mW Input Power

Figure 3 represents the output signal power for different set-ups with respect to wavelength variation. The variations in output signal power are from 22.34 dBm to 28.83 dBm for (Er-Yb + Raman) hybrid amplifier, 2.28 dBm to 15.13 dBm for (Raman + Er-Yb) hybrid amplifier, -0.24 dBm to 13.98 dBm for Raman amplifier and -9.48 dBm to 6.41 dBm for Er-Yb amplifier received respectively. But for (Er-Yb + Raman) hybrid optical amplifier output signal power received is maximum with variation is (< 6.49 dBm) which is very small comparison to other optical amplifier configurations.

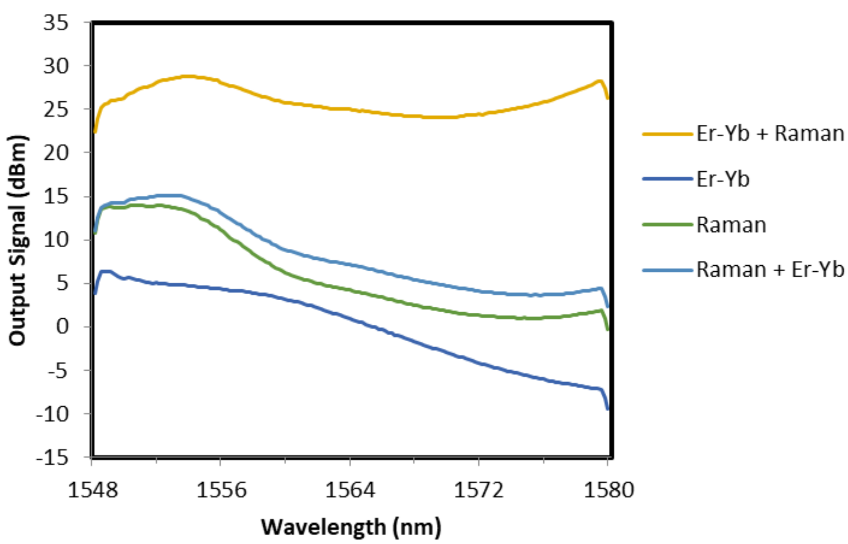

Figure 3 Diagram Showing Output Signal Power variation for different single and hybrid optical amplifiers at 1 mW Input Power

Figure 4 shows the pictorial representation of Q - Factor as a function of Time (Bit Period). In this, for (Er-Yb + Raman) hybrid amplifier received maximum Q – Factor (6.61) comparison to other single and hybrid optical amplifiers.

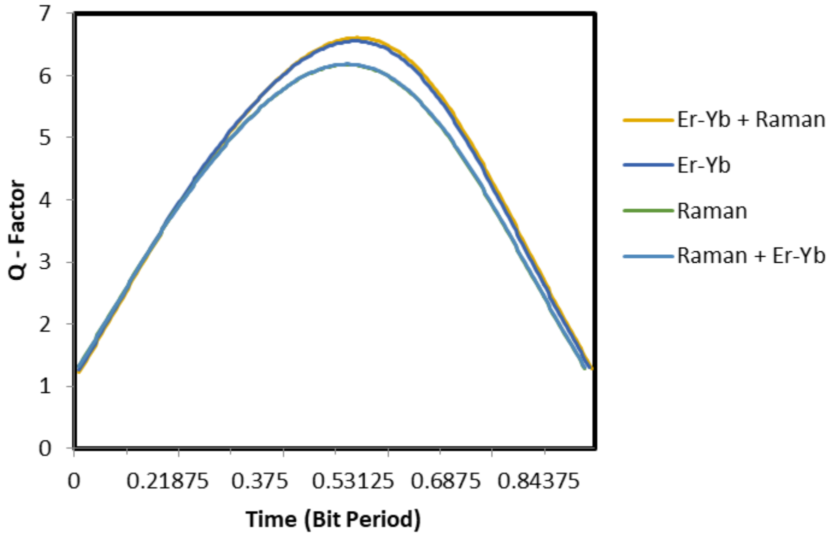

Figure 4 Diagram Showing Q - Factor Variation for Different Single and Hybrid Optical Amplifiers at 1 mW Input Power

For better results, the log of BER should be a minimum value for the optical communication system. After comparing the results for the entire single and hybrid optical amplifiers, we get the minimum value for a log of BER (-22.86) for the proposed HOA scheme (Er-Yb + Raman) shows in the

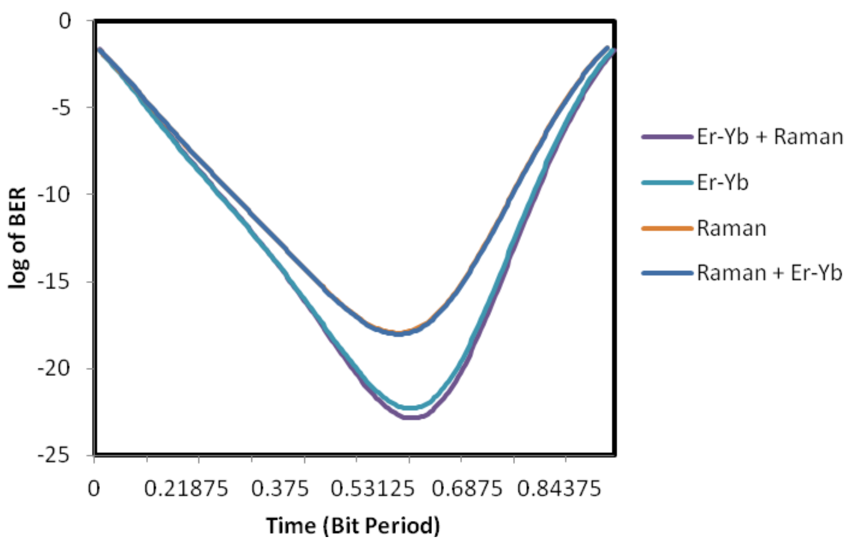

Figure5

Diagram Showing log of BER Variation for Different Single and Hybrid Optical Amplifiers at 1 mW Input Power

Figure 6 represents the Eye Height opening for different optical amplifier configurations. In this graphical representation, we see that for (Er-Yb + Raman) hybrid optical amplifier the Eye Height received is a maximum value (0.0291 a.u.) comparison to other optical amplifier configurations.

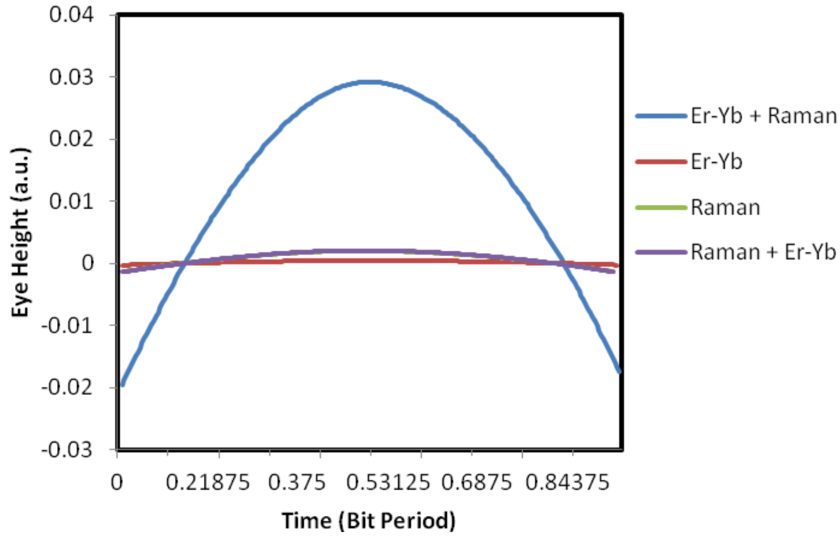

Figure 6 Diagram Showing Eye Height variation for different single and hybrid optical amplifiers at 1 mW Input Power

After comparing all the results, the (Er-Yb + Raman) hybrid optical amplifier configuration gives more appropriate results than to the other optical amplifier configurations for the wavelength span from 1548 nm to 1580 nm.

4. Conclusion

The single and hybrid amplifier configurations for 160 × 10 Gbps at 0.2 nm wavelength spacing were successfully designed and implemented using Optisystem software. The optimization of this work is to utilize the optical amplifiers for different combinations. The achievement of single and hybrid amplifiers was evaluated in terms of gain, signal power, Q – Factor, log of BER and Eye Height. The simulation results show that (Er-Yb + Raman) with 1 mW signal power performed better than other configurations.

In conclusion, this (Er-Yb + Raman) hybrid optical amplifier model has provided higher value of gain with a lesser gain discrepancy for 1 mW signal power. The output power is also the excessive value at minimized wavelength spacing without applying any kind of gain flattening methods. The analysis results that an acceptable Q-factor is obtained for all the single and hybrid configurations. The received high gain shows the practicality of proposed hybrid amplifier for long-haul DWDM applications with higher data rates.

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