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Performance Analysis of Different Combination of EDFA/RFA for WDM System

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Abstract —We investigated the performance of RAMAN-EDFA, RAMAN-EDFA-RAMAN, EDFA-RAMAN, EDFA-RAMAN-EDFA hybrid Amplifiers in C+L band for 16 channel WDM systems with each channel having data rate 2.5 Gbps at channel spacing of 100 GHz. The performance has been compared on the basis of different fiber length at dispersion equal to 16.75 ps/nm/km in terms of Q- factor, BER and Gain. The results showed that EDFA - RAMAN - EDFA provides the highest Q-factor, lowest BER and maximum eye opening up to distance of 100 km as compared to RAMAN—EDFA, RAMAN-EDFA-RAMAN, EDFA-RAMAN hybrid amplifiers combination. EDFA-RAMAN is the best alternative to RAMAN - EDFA in WDM system.

Keywords-EDFA; RAMAN; WDM; Hybrid Optical Amplifier; DWDM; Optisystem.

I. INTRODUCTION

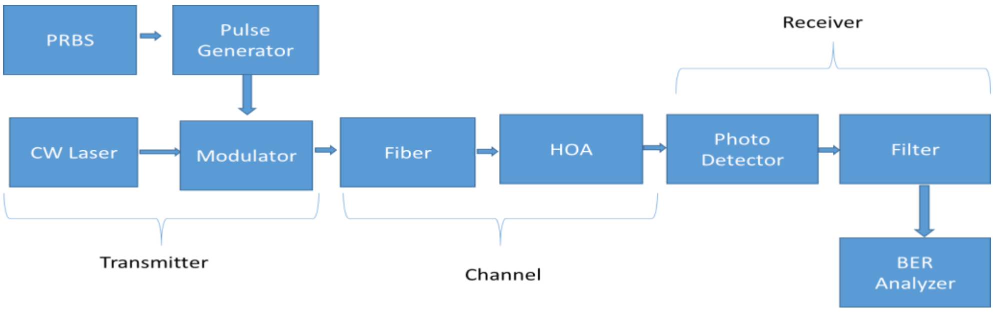
An important aspect of an optical fiber communication link is that many different wavelengths carrying independent signal channels can be sent along a single fiber simultaneously. In particular, telecommunication service providers are using this feature in the low-loss 1300-to-1600-nm spectral region of optical fibers. [1] There has been a strong demand in high capacity signal transmission systems and networks in recent. To increase data transmission capacities, several methods are proposed by adding more channels in the wavelength division multiplexing (WDM) system, so that spectral efficiency needs to be upgraded. To overcome these problems, the DWDM systems have been demonstrated using several types of wideband optical amplifiers. In literature various gain flattening techniques have been used to reduce the gain variation over the bandwidth. Different compensation methods were studied in past and based on these methods efforts were made to increase the gain flatness of EDFA. The combination distributed Raman amplifier and EDFAs present better performance than conventional EDFA only systems [2]. Hybrid EDFA/RFA could have the benefits of both EDFAs and RFAs, hence some efforts have been carried on to offer efficient construction for hybrid EDFA/RFAs [3]. The parameters of the EDFA and RFA used in hybrid EDFA/RFA i.e., doped fiber length, Er3+ concentration, pump power, pump wavelength, etc. can be varied to obtain the flattest operating gain spectrum. To perform amplifier gain equalization, one of the options is to insert within the amplifier a gain flattening filter (GFF) precisely tailored to the inverse gain curve [4]. [5] Optical amplifier basically amplifies input signal coming to it directly without converting it to an electrical signal, with the use of pumping. There are many amplifiers which are used for amplification of signals. Every amplifier has its own characteristics. In this paper we used Raman fiber amplifier and Erbium doped fiber amplifier. We have investigated the hybrid scheme of these amplifiers in C+L band.

It was realized that due to fiber imperfections and also the non-linear gain provided by different amplifiers, the gain is not flat over the working frequency range of a DWDM optical communication system. Gain flattening can be a significant area of research for DWDM optical communication system. Recent optical communication systems are working in C and L band and thus, the present work should be focused on the gain flattening in both C and L bands. Gain flattening can be achieved by using individual amplifiers like Raman amplifier, EYCDFA, EDFA, SOA etc., but individually these amplifiers will not be able to provide a flat gain over larger bandwidth, a hybrid amplifier which can be a combination of Raman amplifier and EDFA can be used to obtain a flat gain over larger bandwidth and to transmit signal at larger distance. This paper consists of four sections. After the introduction, Section II represents the experimental setup and description of its components. In Section III, simulation results have been reported and Section IV summarizes the conclusion about the performance of the system.

II. SIMULATION SETUP

An optical transmission link consists of three stages i.e. transmitter, optical amplifier and receiver as shown in Fig.1.Each Transmitter section consists of the data source, electrical driver and laser source and amplitude modulator. Data source generates a pseudorandom binary sequence of data stream. Electrical driver here generates data format of the type NRZ rectangular. Laser block shows simplified continuous wave `Lorentzian (CW) laser. The output from the driver and laser source is passed to the optical amplitude modulator. The pulses are modulated using MZ modulator at 10Gbps data rate. The amplitude modulator is a sine square Mech-Zehnder modulator with an excess loss of 3 dB. Single receiver is composed of optical fabry perot filter. Bidirectional fiber is used for Raman interaction. Dispersion Compensation Fibers DCFs and Single Mode Fibers SMFs are used to propagate the signal. Optical de-multiplexers are used for de-multiplexing of signals at the output. Optical receiver is used at the output. In this setup, 16 channel WDM system is implemented with Raman EDFA hybrid amplifier combination in C+L bands. Signal is transmitted over (20, 40, 60, 80, 100, 120, and 140) km distance in DWDM system. Table 1 shows parameters used in simulation.

Fig. 1 Block diagram of simulation setup



III. RESULTS AND DISCUSSIONS

Performance is compared in terms of Q-factor, BER and output power with respect to the system fiber length is analyzed. Q-factor and the BER are inversely proportional to each other as the q-factor increases the BER value should decrease. The performance of 16 × 2.5 GB/s DWDM system using combinations of HOA i.e. RAMAN-EDFA, EDFA-RAMAN, EDFA-RAMAN-EDFA, RAMAN-EDFA-RAMAN is analyzed for channel spacing i.e.100GHz. This simulation is done for 8-channel and 16-channel transmitter at 10Gbps and 40Gbps data rate.

A. For 8 Channel

For EDFA-RAMAN-EDFA hybrid optical amplifier at -20 dbm input power, for fiber length 10 km the q-factor obtained is 4.921 and BER obtained is 3.97x10^{-7} , at 20 km q-factor is 4.1170 and bit error rate is 1.713x10^{5}, at 120km Q-factor is 3.3830 and BER is 0.0003075 and for 140 km q-factor and BER is 3.31218 and 0.0004624 respectively.

B. For 16 channel.

We analysed the system for -20dbm input power over varying distance of optical fiber for different proposed combination of hybrid optical amplifier .The wavelength range for the 16channel transmitter is 1550 nm to 1565nm with the wavelength spacing of 0.8nm between channels, Higher input bitrates like 10 Gbps per channel, for channel length 20 km and 140km for Raman pump power of 100mw the eye diagram is poor and distorted and Q-factor obtained is around 3 and higher bit error rate is obtained. But for bitrate of 2.5gbps and less optical fiber length like 10km the Q-factor obtained is 55.7698 and bit error rate is very less in simulation that it shows value 0.

The hybrid optical amplifier combination scheme for RAMAN and EDFA are considered and analysed for the performance factors: Q-factor, Gain, BER, Noise figure with respect to varying distance in km.

1. EDFA-RAMAN:
   With increase in fiber length the q-factor decreases and BER increases, for 20 km the q-factor is 57.2998 and BER is very less, for 100 km the the q-factor reduces to 9.10 and BER has increased to 3.75x10^{-20} which is still acceptable in terms of system parameter and for 140 km the q-factor is very low at 3.26 and BER is high at 0.004748. The Gain variation for the fiber length from 20 km to 140 km is from 27.26 to 9.88 dbm.
2. RAMAN-EDFA:
   The Q-factor of the system is maximum at value 38.14 for short fiber length of 20 km with the BER 8.46x 10^{-319} and q-factor is at its lowest value of 2.20 at the increased fiber length of 140 km with its increased bit error rate of 0.0122876. The Gain variation is from 26.79 to 14.27 for fiber length 20 km to 140 km.
3. EDFA-RAMAN-EDFA:
   The Q-factor of the system is maximum 57.10 with very high BER of ~0 at 20km fiber length and minimum 3.25 at 140 km with BER of 0.000501056 at 140 km fiber length. The Gain of the system varies from 29.77 to 21.64 dbm
4. RAMAN-EDFA-RAMAN:
   The Q-factor at short fiber length of 20 km is maximum 38.17 with BER 3.77x 10^{-319} and q-factor is at its lowest for the system with fiber length 140 km at 2.20 with BER 0.0122, the Gain of the system varies from 34.54 dbm to 19.55 dbm

The simulation shows that the q-factor is inversely related to the BER of the system for hybrid optical amplifier, from the proposed combination the performance of gain flattening for the 16 channel wdm system the HOA combination EDFA-RAMAN-EDFA amplifier shows best result in terms of Q-factor, BER, and Gain, Also the gain flattening effect of EDFA-RAMAN-EDFA is better than other combination.
As shown in the simulation result graph of all the combination of HOA in terms of gain is shown in figure 3.

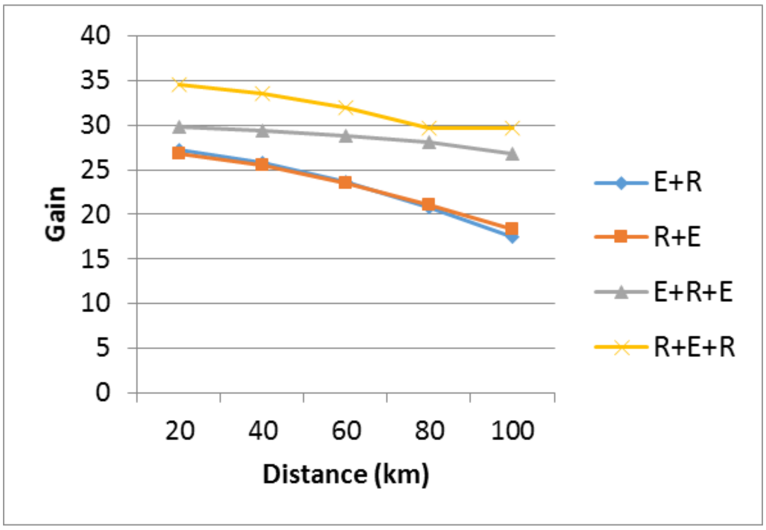


Figure 2. Comparison of gain variation for different combination of HOA.

In order to observe the performance of different amplifiers (Raman-Edfa, Raman-Edfa-Raman, Edfa-Raman, Edfa-Raman-Edfa), the quality factor versus transmission distance graph is plotted. As shown in figure 4.

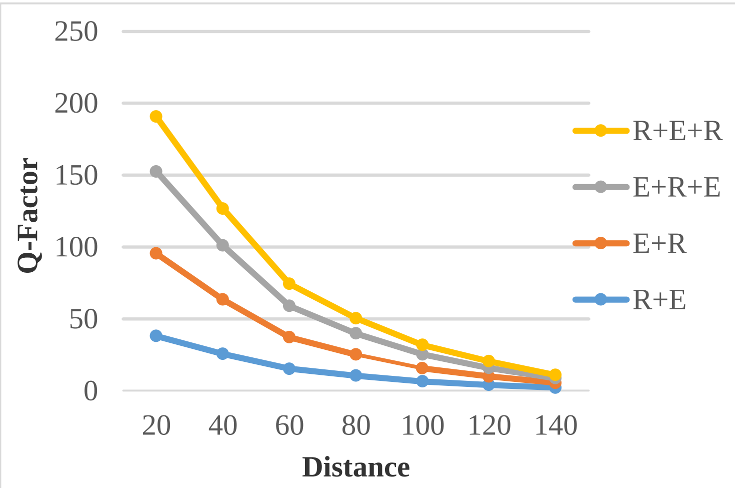
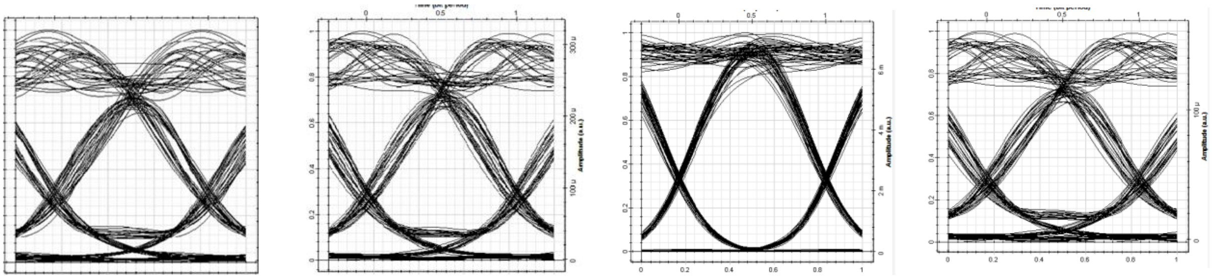


Figure 3. Performance of Q-factor with varying distance

Table 1. Parameters of simulation for 16 channels

WDM Transmitter ports	16
Frequency	195THz
Frequency spacing	100GHz
Power (input)	-20 dbm
Bit rate	10gbps
Modulation Type	NRZ
Raman Amplifier Length	10 km
EDFA Length	8 m
Optical Fiber Length	20, 40, 60, 80, 100, 120, 140 km
Photodetector	PIN



a) b) (c) (d)

Figure 4. Eye opening for HOA combination (a) R/E at 100 km, (b) E/R/E at 100 km, (c) R/E/R at 100 km, (d) E/R at 100 km.

IV. CONCLUSIONS

In proposed work, we have implemented Raman- Edfa hybrid scheme for C+L band. From simulation results, it has been concluded that RAMAN – EDFA – RAMAN hybrid amplifier gives better results for gain flattening effect as shown in figure2. Than other hybrid amplifiers i.e. RAMAN-EDFA, RAMAN-EDFA-RAMAN, EDFA-RAMAN, and EDFA-RAMAN-EDFA. In C+L Band, gain is flat in the range of 60nm, which is quite efficient value and value of noise figure is below 4db which is tolerable. In proposed work gain has been flattened without using any gain flattening technique, which is a cost effective solution.

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