PERFORMANCE INVESTIGATION OF OPTICAL AMPLIFIER FOR 80 ×10 GBPS WDM SYSTEM IN THE PRESENCE AND ABSENCE OF NON-LINEARITIES

Sapna Rani[1], Ramandeep Kaur[2]

[1]Student, [2]Assistant Professor, Department of Electronics and Communication Engineering,

U.C.O.E, Punjabi University, Patiala, (India)

ABSTRACT

In this paper, we have investigated Wavelength Division Multiplexed (WDM) systems at 10 Gb/s for 80 channels without any inline amplification. Further, the proposed system is analyzed for Erbium Doped Fiber Amplifier (EDFA), Semiconductor Optical Amplifier (SOA) and Raman Amplifiers (RA) and the performance has been compared on the basis of transmission distance with and without nonlinearities. We analyzed the results in the terms of maximum output power and Quality factor. It is observed that EDFA is best suitable amplifier due to its high gain performance.

Keywords: WDM, EDFA, SOA, RAMAN

I INTRODUCTION

The Wavelength Division Multiplexing (WDM) is to use multiple sources operating at slightly different wavelengths to transmit several independent information streams over the same fiber. Dramatically surge in WDM popularity started in early 1990s as electronic devices neared their modulation limit and high speed equipments are complex. Mid of the 90's combination of Amplifiers and WDM was used to boost fiber capacity to even higher levels and to increase the transmission distance [1].With the use of optical fiber amplifiers the performance of the optical system is boost up to increase the repeater spacing and bit rate. EDFA has been used as booster and inline amplifier to transmit optical signals over thousands of kilometres [2]. EDFAs are having low noise figure and have a good gain bandwidth and can amplify multichannel signals on different wavelengths simultaneously. It is also reported that under deeper saturation or having steeper saturation characteristic EDFA would result in less BER impairment. It shows that there are need to optimization between the EDFA power and distance [3].

Fiber Raman amplifiers (FRA) in long-distance transmission line improves noise performance. Distributed Raman amplifier reduces the nonlinear penalty of fiber systems, and this improves the overall system performance. Raman amplifiers have become essential in overcoming the limitations of the bandwidth, noise figure (NF), and output power of conventional doped fiber amplifiers [4] [5]. Semiconductor optical amplifier (SOA) is of great interest for its potential as a low-cost, large wavelength range, small form factor, and low power consumption. SOAs have various applications using the nonlinear effect, such as optical switching, wavelength conversion and mid span spectral inversion [6] [7].

Kim et al. [7] performed transmission of 10 Gbps optical signals with $LiNbO_3$ transmitter using semiconductor optical amplifier (SOA) as booster amplifier. Optical signal transmitted over 80 km through Standard single mode fiber (SSMF). They described the numerical models used for SOA's, optical fibers and receivers and validated them using simulation results. Further, it was found the appropriate parameters of input signals for SOA's, such as maximum dynamic range, extinction ratio, rising/falling time, and chirp parameter and available maximum output power.

Yeh et al. [8] used a coupled structure and the new S-band amplifier module to retrieve the wide gain bandwidth from S- plus C-band. They investigated and experimentally demonstrated a coupled structure and S- plus C-band EDFA module with 96 nm gain bandwidth of 1480–1576 nm. For the proposed EDFA, 30 dB peak gain with 8.2 dB noise figure and 36.2 dB peak gain with 7.2 dB noise figure was observed at 1506 and 1532 nm, respectively, while the input signal power of −25 dBm was observed. In addition, the proposed amplifier module also provided a broadband ASE light source from 1480 to 1578 nm while the optical output level above −40 dBm.

Singh et al. [9] investigated the past-, pre- and symmetrical power compensation method for different positions of SOA in fiber link. This paper deals with the placement of semiconductor optical amplifier for 10 Gb/s non-return to zero format in single mode and dispersion-compensated fiber link. It concluded that the post-power compensation method had good performance in terms of bit error rate, eye closure penalty and received power as compared to pre- and symmetrical power compensation methods. The bit error rate and eye closure penalty increases with increase in the signal input power. Further, it was found that the pre-power-compensated method in single span is best for pre-amplification of very low signal input power.

Guimaraes et al. [10] demonstrated the performance of hybrid optical amplifier when it was employed as pre-amplifier and described its application on 40 Gbps systems. In that work it was shown that for error rate 10^{-12}, hybrid pre-amplifier provides an improving in the system power penalty of 3.2 dB when compared with the back to-back values. It also demonstrated that FOPAs had a similar EDFAs performance for inline amplification. The higher performance obtained with the hybrid pre-amplifier was due to the fact that we designed the FOPA to operate in the saturated regime, therefore it was acting as a noise limiter.

Goyal et al. [11] analyzed the performance and feasibility of a hybrid wavelength division multiplexing/ time division multiplexing passive optical network (WDM/TDM) PON system with 128 optical networks units (ONUs). The proposed optical networks based on FTTH (fiber to the home network). The users can transmit data, voice and video signals through the same fiber. The wavelengths in the range of 1480–1500 nm was using to transmit the data and voice component with 1.25 Gb/s and 1550–1560 nm was using for video signals with 0.8 Gb/s. It had been observed that the most suitable data format for data transmission is NRZ Rectangular.

Kaler et al. [12] simulated 16 × 10 Gbps WDM system based on optical amplifiers at different transmission distance and dispersion. The hybrid optical amplifier RAMAN-EDFA provided the highest output power (12.017 and 12.088 dBm) and least bit error rate (10^{-40} and 9.08 $\times 10^{-18}$) at 100 km for dispersion 2 ps/nm/km and 4 ps/nm/km respectively. In that work it was shown, the RAMAN-EDFA was a promising alternative to EDFA, SOA, and RAMANSOA in optical transmission.

In the literature survey, we have studied various research papers. Most of the papers are based upon downlink only [6, 9, 10], on lesser data rates (1.25 Gbps [10], lesser number of users (16 [12]), more channel spacing and up to short distance (28 km [11], 80 km [6], 49+92 km NZDF [10], 100 km [11]). As the demand of the number of channels is increases, wavelength division multiplexer support more number of channels with good quality and efficient cost. To increase the number of channels, the components used in the network should be improved by using distributed amplifier with their different pumping schemes, inline amplifiers and semiconductor amplifiers. We have to find out the best bit rate, modulation formats of transmitter, dispersion of the fiber and their pumping scheme to have considerably better performance. The simulation setup should observe with changing the length of fiber.

In this paper, the previous work extends in the context of 80 channels for existing amplifiers used as preamplifiers. Further the performance of EDFA, SOA and RAMAN for different distance in the term of output power, Q factor has been compared. There also shown the eye opening of amplifier in the presence and absence of non linearities. The paper is organized into four sections. In Section 2, the optical simulation setup is described. In Section 3, comparison results have been reported for the different distance with non linearities and without non linearities and finally in Section 4, conclusions are made.

II SIMULATION SETUP

In this paper 80 channels are transmitted at 10 GB/s data rate with 100 GHz channel spacing. Transmitter is combination of NRZ data format (electrical driver) which converts the logical signal to corresponding electrical signal. The logical signal is fed into the external Mach-Zehnder modulator, where the input signals from data source is modulated through a carrier (optical signal from the laser source). The amplitude modulator is a sine square with an excess loss of -3 dB. A booster amplifier as preamplifier is used after multiplexing signals are launched into bidirectional fiber at different transmission distance. A transmitter compound component is built up using transmitters.

The 80 channels beams have random laser phase and ideal laser noise bandwidth. The simulations setup consisting EDFA, SOA and RAMAN at different transmission distance are shown in Fig. 1. This optical signal is transmitted and measured over different distances at 16 ps/nm/km dispersion. The modulated signal is converted into original. Here, we simulated the setup in the presence of and in the absence of non linearities. The Rayleigh scattering, PMD effect and SBS non linearities disable or enable for the simulation.

The optical signal is broadcasted and determined over different distances, i.e. 80 channels are simulated at length distance from 160 to 195 km at 16 ps/nm/km dispersion. The modulated signal is switched into original signal with the help of PIN photodiode and filters. A compound receiver is used to detect all 80 signals and converts these into electrical form. Different types of optical amplifiers are also applied at the receiver side. The setup is repeated for measuring the signal strength by using different amplifiers, i.e. EDFA/SOA/RAMAN. For all the cases, we have evaluated maximum Q factor, output power and eye opening.

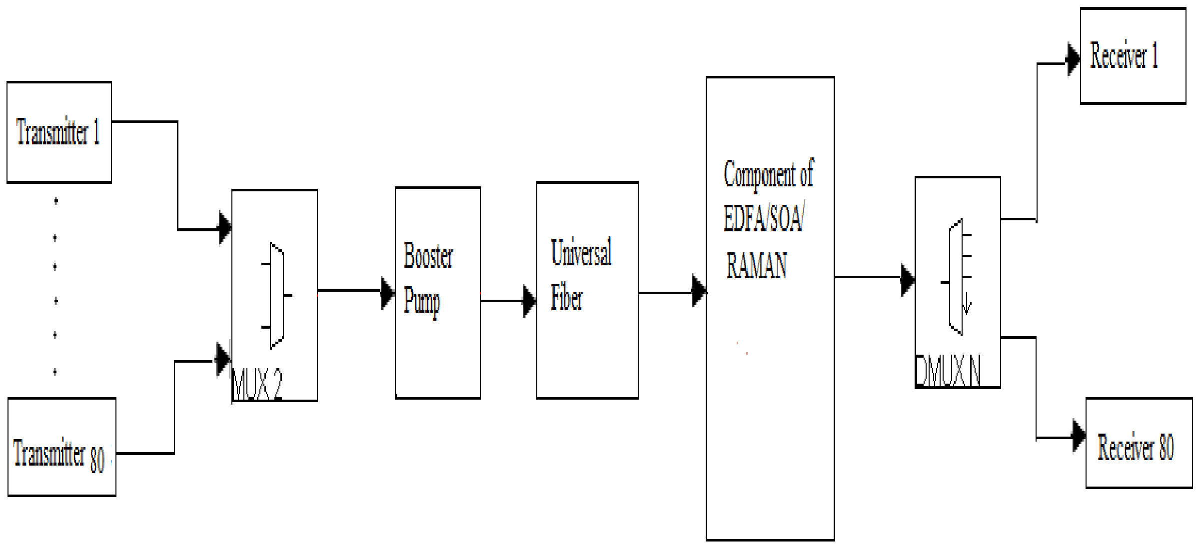


Fig. 1. Block Diagram for Simulation Setup.

III RESULT AND DISCUSSION

The different optical amplifiers (RAMAN, EDFA and SOA) have been evaluated for 80 ×10 Gbps WDM system in the term of received maximum Q factor and maximum output power (dBm). To analyze the system, the results of the first channel have been taken. Output power and Q factor for all cases can be seen for existing optical amplifiers that as the line distance varied.

Fig. 2 shows the graphical representation of output power as a function of distance in the absence of nonlinearities. The better output power is provided by the EDFA amplifier (-11.27 dBm) at 160 km length and also for the worst case at 195 km, it becomes -13.2 dBm. The variation in output power for EDFA, SOA and RAMAN is -11.27 to −13.2 dBm, -13.6716 to -15.6016 dBm and -14.7096 to -16.6396 dBm, respectively.

If the non linearities are considered, the output power for 80 channels for the different amplifiers at distance varying 160 to 195 km shown is fig 3. The output power decreases due to the fiber non-linearities and fiber attenuation. In this case EDFA provides better output power (-17.155 dBm) and also for the nastiest case at 195 km it becomes -19.085 dBm as compared to other amplifiers as shown in Fig. 3. The variation in output power for EDFA, SOA and RAMAN is -17.155 to −19.085 dBm, -18.4006 to -20.33 dBm and -19.7 to -21.63 dBm, respectively.

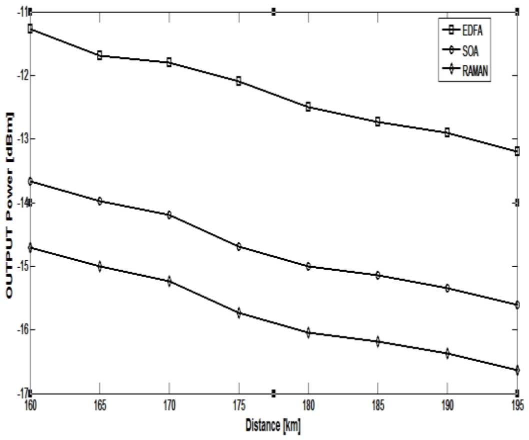


Fig. 2

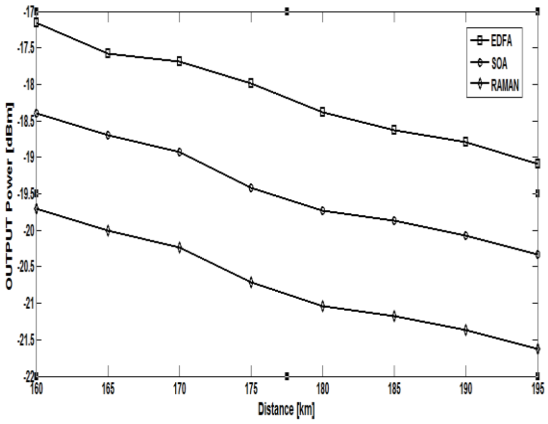


Fig. 3.

Fig. 2. Output power vs. length in the absence of nonlinearities.

Fig. 3. Output power vs. length in the presence of nonlinearities.

Fig. 4 depicts the graphical representation of Q factor as a function of distance in the absence of non linearities. The better Q factor is provided by the EDFA amplifier (13.31) and also for the nastiest case at 195 km, it becomes 11.34. The variation in Q factor for EDFA, SOA and RAMAN is 13.31 to 11.34, 12.571 to 10.601 and 10.711 to 8.741 respectively. When we compare these optical amplifiers EDFA provides the better result as compared to other amplifiers.

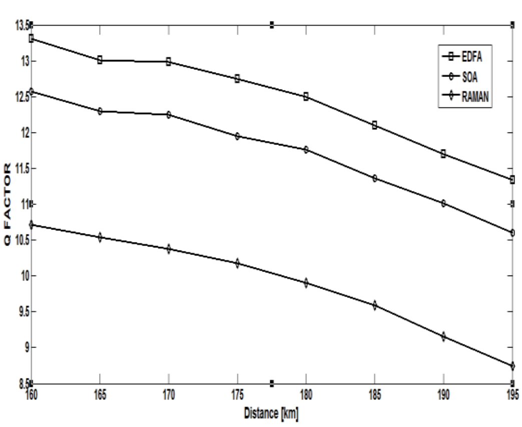


Fig 4

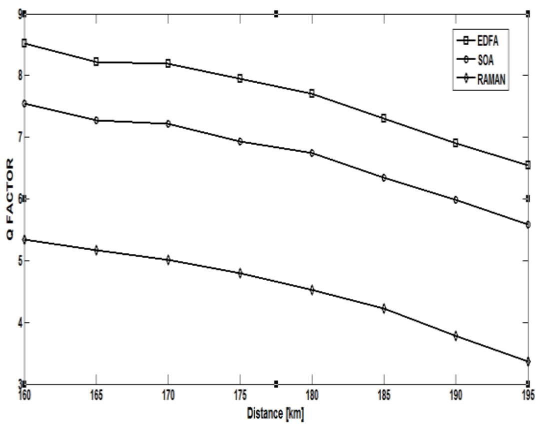


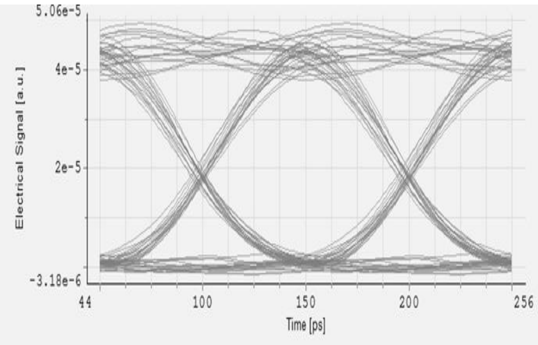
Fig. 5.

Fig 4. Q factor vs. Distance in the absence of nonlinearities.

Fig. 5. Q factor vs. Distance in the presence of nonlinearities.

If nonlinearities are considered, better Q factor is provided by the EDFA amplifier as shown in Fig. 5. The variation in Q factor for EDFA, SOA and RAMAN is 8.518 to 6.548, 7.551 to 5.581 and 5.34 to 3.37, respectively. At 180 km SOA and RAMAN have comparable Q factor.

As above discussion and results, we notice that the response of the EDFA is better than other amplifiers, RAMAN and SOA. So with the help of EDFA, we should increases the number of channels at better response. Fig. 6 and 7 shown that the eye opening of the Erbium Doped Fiber Amplifier (EDFA) in the absence of and in the presence of Non linearities. EDFA have more eye opening or less crosstalk at the distance 175 km in the absence of non linearities then the presence of non linearities.



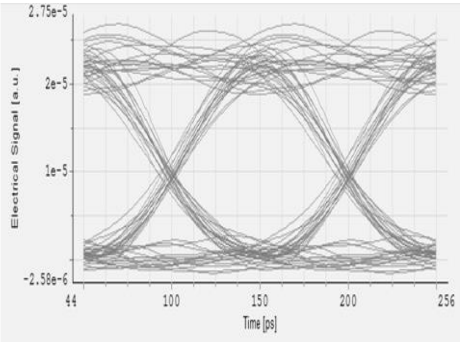


Fig . 6 **Fig . 7**

Fig . 6. Eye opening of EDFA at the distance 175 km in the absence of non linearities

Fig . 7. Eye opening of EDFA at the distance 160 km in the presence of non linearities

IV CONCLUSION

In this work, we have evaluated the performance of 80×10 Gbps Wavelength Division Multiplexer (WDM) system using optical amplifiers Erbium Doped Fiber Amplifier (EDFA), Semiconductor Optical Amplifier (SOA) and Raman Amplifiers in the presence and in the absence of nonlinearities without any inline amplification. Further, the proposed system is analyzed for EDFA, SOA and Raman amplifiers and the performance has been compared on the basis of transmission distance with and without nonlinearities. In this paper, 80 channels are simulated at length distance from 160 to 195 km, in the presence and absence of non linearities. It is observed from all cases that EDFA is best suitable amplifier due to its high gain performance.

REFERENCES

[1] G. Keiser, "*optical fiber communication*", 3rd Ed, Mc Graw-hill, Boston, 2000

[2] N. Kikuchi, S. Sasaki, "*Analytical evaluation technique of self-phase modulation effect on the performance of cascaded optical amplifier systems*", IEEE J. Lightwave Technology, 13(5), 1995, 868–878.

[3] R.S. Kaler, A.K. Sharma, T.S. Kamal, "*Comparison of pre-, post- and symmetrical dispersion compensation schemes for 10 Gb/s NRZ links using standard and dispersion compensated fibers*", Optical Communication, 209(1–3), 2002, 107–123.

[4] M.N.Islam, "*Raman Amplifiers for Telecommunications-2 Subsystems and Systems*", Springer, 2004.

[5] S. Singh, R.S. Kaler, "*Wide-band optical wavelength converter based on four wave mixing using optimized semiconductor optical amplifier*", Fiber Integrated Opt., 25(3), 2006, 213–230.

[6] Xing Wei, Yikai Su, Xiang Liu, Juerg Leuthold, and S. Chandrasekhar, "*10-Gb/s RZ-DPSK Transmitter Using a Saturated SOA as a Power Booster and Limiting Amplifier*", IEEE Photonics Technology Letters,16(6), june 2004.

[7] Y. Kim, H. Jang, Y. Kim, J. Lee, D. Jang, J. Jeong, "*Transmission performance of 10- Gb/s 1550-nm transmitters using semiconductor optical amplifiers as booster amplifiers*", IEEE J. Lightwave Technology, 21(2), 2003, 476–481.

[8] C.H. Yeh, C.C. Lee, S. Chi, "*S-plus C-band erbium-doped fiber amplifier in parallel structure*", Optical Communication, 241, 2004, 443–447.

[9] S. Singh, R.S. Kaler, "*Placement of optimized semiconductor optical amplifier in fiber optical communication systems*", Optik, 119, 2008, 296–302.

[10] A. Guimarles, J.M. Chavez Boggio, J.D. Marconi, F.A. Callegari, H.L. Fragnito, "*High performance hybrid EDFA-FOPA pre-amplifier for 40 Gb/s transmission*", in: IEEE Conference on Lasers & Electro-Optics, 2005, 981–99.

[11] R. Goyal, R.S. Kaler, "*A novel architecture of hybrid (WDM/TDM) passive optical networks with suitable modulation format*", Optical Fiber Technology, 18, 2012, 518–522.

[12] R.S Kaler, "*Simulation of 16 × 10 Gb/s WDM system based on optical amplifiers at different transmission distance and dispersion*", Optik, 123, 2012, 1654– 1658.