Performance Analysis of Different Hybrid-Optical Amplifiers

[1]Chirag Saini, [2]Gaurav Agarwal, [3]Vikash Patnaik,[4]Jabeena A
School of Electronics Engineering,VIT University,
Vellore-632014, Tamil Nadu, India. Phone- +919790511568

Abstract: *This paper analyzesoptical fiber amplifiers namelyRaman amplifiers RAs, semiconductor optical amplifiers SOAs,Erbium doped fiber amplifiers EDFAs and their Hybrid configurations, namely EDFA-EDFA, EDFA-SOA, Raman-SOA and Raman-EDFA. The hybrid optical amplifiers operating at a bit rate of 10 Gb/s for 96 channels are simulated using OptSim and their Q-factor, output power, eye opening, eye closure and bit error rate are compared by varyingtransmission distances from 60 to 180 km and keeping the dispersion constant at 2 ps/nm/km both in the presence and absence of non-linearities. Furthermore, we go through some of the main characteristics of these amplifiers and superiority of Hybrid optical amplifiers over the basic optical amplifiers. Each type of amplifier is suitable for certain applications depending on these characteristics and the transmission distance.*

Keywords:*BER, dispersion, Hybrid optical amplifier, non-linearities.*

I. INTRODUCTION

Optical fiber communication has become the backbone of today's data communication networks. But similar to the other transmission media, it also suffers from losses during transmission. As the optical signal propagates along anoptical fiber it necessarily gets attenuated along the fiber path. In addition to attenuation, it also suffers from polarization and chromatic dispersionsif the data rate is too high, which is practically a necessity in many applications. Hence, to make up for attenuation, optical fiber amplifiers are used. Furthermore their combination is what is called a Hybrid Optical amplifier (HOA). However, their introduction into the system causes many additional problems. HOA configuration utilizes collectively the advantages and drawbacks of the individual amplifiers. But different transmission distances demand the advantages of different HOA configurations. We hereby simulate and find out which configuration is suitable up to what distances.

II. Characteristics of different Optical amplifiers

2.1 Erbium Doped Fiber Amplifier (EDFA)

Some characteristics of EDFA are as follows, usually the EDFAis pumped at 980 nm or 1480 nm. The former has shown gain efficiencies of around 10 dB/mW, while the latter provides efficiencies of around 5 dB/mW. Typical gains are of the order of 25 dB. Typically noise figure lies between 4-5 dB with forward pumping and 6-7 dB for backward pumping, assuming 1480 nm pumping light was used. Current repeater spacing is around 80-100 Km for a speed of 10 Gb/s [1]. Gain spectra of EDFA are non-uniform. A notch filter can be employed for gain flattening. EDFA noise figure depends on both pump power and the amplifier length for larger the pump power better will be the noise figure. The larger the length of the erbium fiber, the more will be the amount of ASE generated, shown in Figure 2.

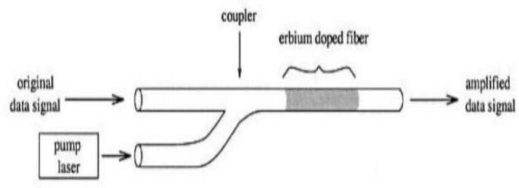

Figure 1.EDFA [2]

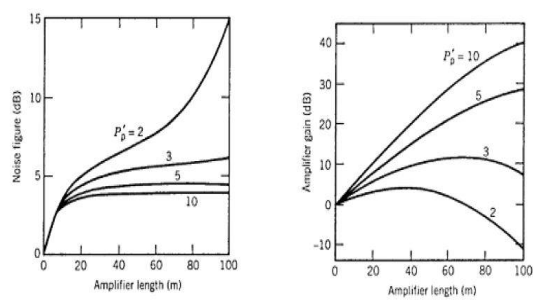

Figure 2. Noise Figure and Gain vs length[3]

2.2 Semiconductor Optical Amplifier (SOA)

It is a modified semiconductor laser. Usually used when a wide range of input power is required to produce a constant output power [4]. Can be used as an optical Post-amplifier. SOA has a short carrier lifetime. SOA are of two different types. Fabry Perot and travelling wave type. FPA has a reflectivity of around 30% of the end mirror while TWTA has about 0.01%. Out of these two TWTA is most widely used due to its large bandwidth, high saturation power, and low polarization sensitivity. SOAs are used to amplify several channels simultaneously. SOA suffers from several non-linear problems, which induce crosstalk in the channel.

2.3 Raman Amplifier (RA)

It is based on Raman Scattering, which is the inelastic scattering of a photon. Raman gain occurs in every fiber. It uses stimulated Raman scattering. Stimulated Raman scattering (SRS) is a type of inelastic scattering that results in a broadband amplification of optical channels [5]. A lower frequency signal photon induces the inelastic scattering of a higher-frequency pump photon in an optical medium in the nonlinear regime. As a result of this, another signal photon is produced. Raman Amplifiers have a wide gain bandwidth, up to 100 nm [6]. It also has an adjustable gain spectrum. It disadvantage is that it requires a high pump power. It was seen that to achieve a gain of 20 dB or more, it required almost three orders of magnitude more pump power than EDFA required [7]. It is also limited by Rayleigh scattering, backscattering of light which introduces crosstalk called Rayleigh crosstalk. Raman Amplifiers are of two types, distributed and discrete.

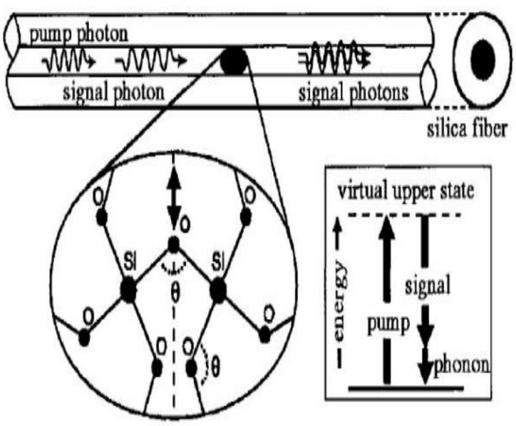

Figure 3. Raman Amplifier [2]

III.Hybrid Optical Amplifiers (HOA)

A HOA is a combination of two or more optical amplifiers, either of the same type or of different type connected together. They provide a higher gain than the individual amplifiers. According to Mohammed N. Islam, the total gain of a hybrid amplifier is equal to the sum of individual gain [8], e.g. $G_{Hybrid} = G_{EDFA} + G_{Raman}$. They are classified into two types, narrowband hybrid amplifier (NB-HA) and seamless wideband hybrid amplifier (SWB-HA). The NB-HA uses distributed Raman amplification together with an EDFA and provides low noise transmission in the C- or L band. The SWB-HA may use both distributed as well as discrete Raman amplifier along with EDFA. The typical gain bandwidth of the NB-HA is 30 nm to 40 nm, whereas that of the SWB-HA is 70 nm to 80 nm. The hybrid configuration also has an improved gain flatness than the individual amplifiers, shown in Figure 4.

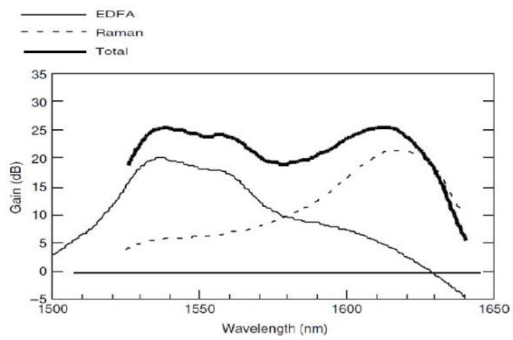

Figure 4. Gain Spectra of a Hybrid Amplifier.

IV. Simulation Scheme and Setup

The Simulation of 96×10 Gb/s WDM System using Hybrid Optical Amplifiers has been performed using OptSim. Wavelength Division Multiplexing (WDM) has been widely used to demonstrate the transmission of high capacity based on 10 Gb/s modulation per wavelength. It is possible to increase capacity while reducing system costs [9]. The 96 channel transmitter, receiver, and optical hybrid amplifier have been used as a compound component to simplify the setup. Before transmission the signal is modulated using NRZ modulation. After pre-amplification, the signal is passed through the various Hybrid Optical Amplifier configurations, namelyEDFA-SOA, RAMAN-EDFA, RAMAN-SOA, EDFA-EDFA as shown in Figure 5 for EDFA-SOA.

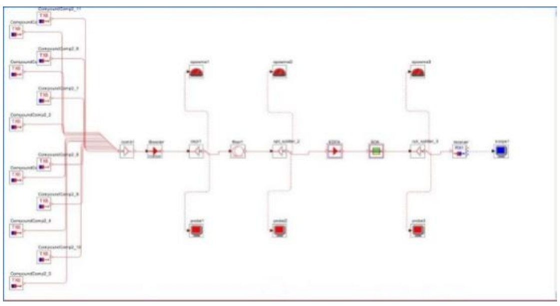

Figure 5. Simulation Setup for EDFA-SOA

In the simulation, transmission distance varies from 80 to 160 km. At the receiver side the signal is demodulated back into electrical form using a photo detector. Various power meters, and probes are used to obtain the power of signals at various points. At the receiver, various parameters like bit error rate, output power, eye closure, eye opening is analyzed in the presence and absence of non-linearities.

V. SIMULATION RESULTS

The simulation was performed and various graphs were obtained for the parameters to be checked with the varying distance.

5.1 Output Power

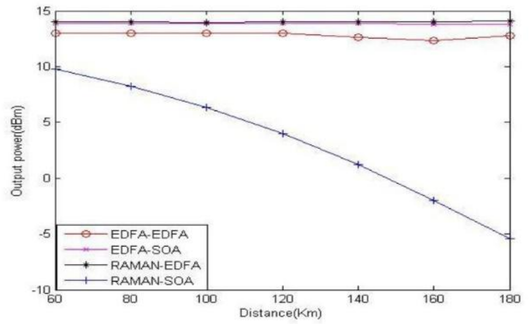

Figure 6. Output power vs Distance

5.2 Bit Error Rate (BER)

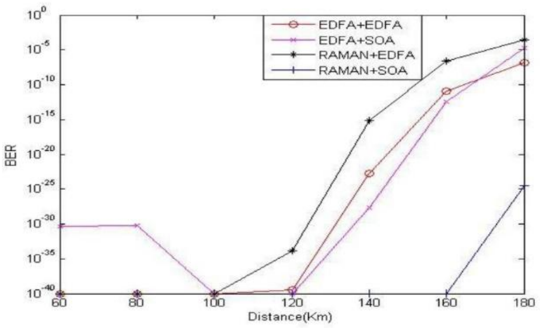

Figure 7.BER vs Distance in absence of non linearities.

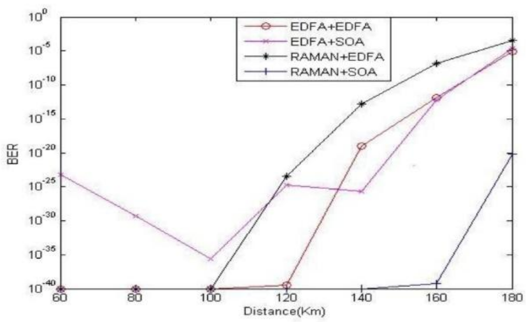

Figure 8. BER vs Distance in presence of non-linearities.

5.3 Quality factor (Q-factor)

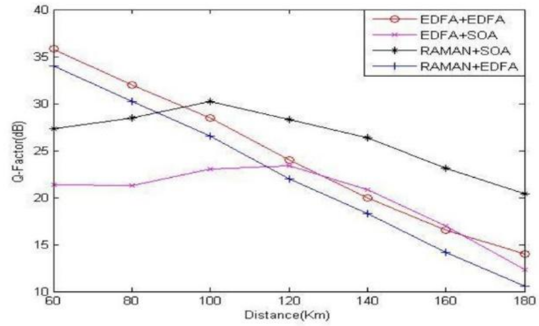

Figure 9.Q-factor vs Distance in absence of non-linearities.

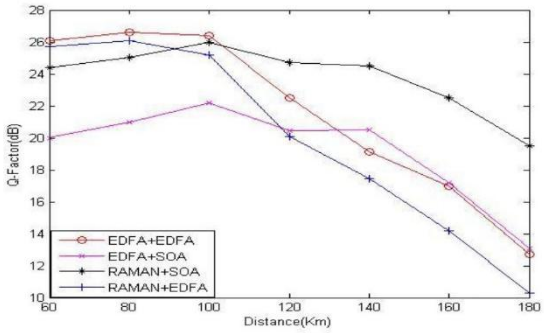

Figure 10.Q-factor vs Distance in presence of non-linearities.

5.4 Eye Opening

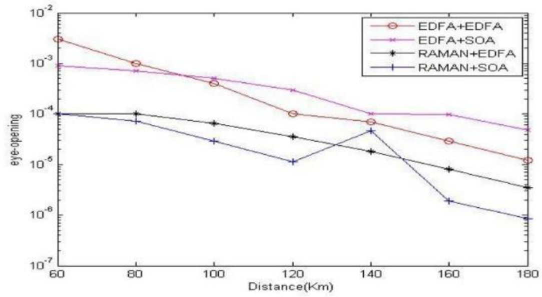

Figure 11. Eye opening vs Distance in absence of non-linearities.

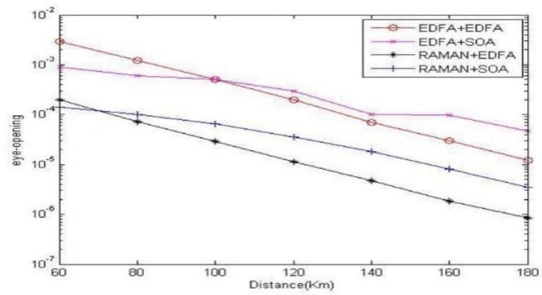

Figure 12. Eye opening vs Distance in presence of non-linearities.

5.5 Eye Closure

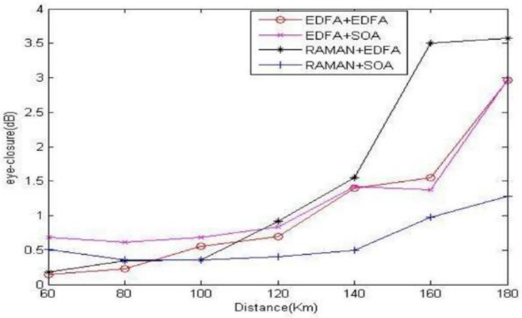

Figure 13. Eye closure vs Distance in absence of non-linearities.

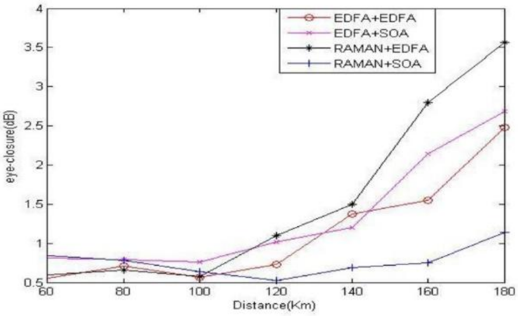

Figure 14. Eye closure vs Distance in presence of non-linearities.

VI. CONCLUSION

Hybrid Optical Amplifiers were assessed both in the presence and absence of non-linearities by varying the transmission distance. From the simulation graphswe conclude that Raman-EDFA hybrid combination provides the highest output power. But as the transmission distance increases beyond 100 km, Raman-SOA performs better as compared to other hybrid amplifiers in terms of quality factor, bit error rate, eye closure and eye opening. And at 160 km Raman–SOA provides a Q-Factor of 17 dB as compared to 13 dB, 11.55 dB, and 11.23 dB provided by EDFA-EDFA, EDFA-SOA, and Raman–EDFA respectively. Furthemore, at 160 km Raman–SOA showed a minimum eye closure of 1.7 dB, which is much better than other Hybrid Optical Amplifiers. Hence it is concluded that Raman-SOA is the most promising hybrid optical configuration to be used as an amplifier at and around 160 km transmission distance.

REFERENCES

[1] X. Zhou, M.Birk "Performance comparison of an 80-Km-per-span EDFA system and a 160-Km hut skipped all-Raman system over standard single-mode fiber", J.Lightw. Technol., vol. 24, no. 3, pp. 1218-1235, Mar. 2006.

[2] Biswanath Mukherjee, "Optical WDM Networks", *Springer*, New York, 2006.

[3] Kikuchi, K., "Generalised Formula for Optical-Amplifier Noise and its Application to Erbium-Doped Fiber Amplifiers", *Electronics Letters*, vol. 26, no. 22, pp. 1851–1853, 1990**.**

[4] K.Morito "Output-level control of semiconductor optical amplifier by external light injection", J.Lightw. Technol., vol. 23, no. 12, pp. 4332-4341, Dec. 2005.

[5] AshwinGumaste, Tony Antony, "DWDM Network Designs and Engineering Solutions", Cisco Press, December 13, 2002. ISBN: 1-58705-074-9.

[6] David R. Goff. *Fiber Optic Video Transmission, 1st ed*. Focal Press: Woburn, Massachusetts, 2003.

[7] Mohammed N. Islam, "Raman Amplifiers for Telecommunications-1 Physical Principle", *Springer*, pp. 9-12, 2004.

[8] Mohammed N. Islam, "Raman Amplifiers for Telecommunications-2 Subsystems and Systems", *Optical Science, Springer*, pp. 430-431, 2004.

[9] Michael J. Yadlowsky, Evelyn M. Deliso, Valeria L. Silva, "Optical Fibers and Amplifier for WDM System", *Proceedings of IEEE*, vol. 85, no.11, pp. 827-841, 1997.