Evaluation of Optical Amplifiers

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Abstract—Optical fiber communication systems are being extensively used all over the world for telecommunication, video and data transmission purposes. The demand for transmission over the global telecommunication network will continue to grow at an exponential rate and only fiber optics will be able to meet the challenge. We have investigated the performance comparison of different optical amplifiers (EDFA,SOA.).The proposed configuration consists of 16, 32 and 64 Gbps channels at speed of 10 Gbps. We have realized the different hybrid amplifiers and their parameters like quality factor, ber, eye opening and jitter at different number of channels.

***Keywords*— RAMAN-EDFA; RAMAN-SOA; SOA EDFA; EDFARAMAN- EDFA; QUALITY FACTOR; BER; EYE OPENING; JITTER**

I. INTRODUCTION

The progress of optical fiber communication has been advancing rapidly for the past two decades. Optical fiber communication systems have a long history and it was realized during the second half of the twentieth century that a greater transmission bandwidth could be achieved by employing optical waves as the carrier [1]. However, this possibility was not exploited until the invention of laser in the 1960s [2]. With the advent of the laser and thus the availability of a coherent optical source, a new era for optical communication was created. Initially, the extremely large losses (more than 1000 dB/km observed in the best optical fibers) made them appear impractical. A breakthrough was reached in 1966, when Kao and Hockham, and Werts discovered the high losses were a result of impurities in the fiber material and that the losses could be reduced by using glass-based optical waveguide [3]. This was realized in 1970, when Kapron, Keck and Maurer [2] succeeded in fabricating a silica fiber with an attenuation of approximately 20 dB/km. This made transmission of a few kilometers commercially feasible. At the same time, GaAs semiconductor lasers, operating continuously at room temperature were demonstrated [1]. First generation light wave systems operating near 0.8 μm became commercially available in 1980 [1] and the systems were operating a bitrate of 45 Mb/s with allowed repeater spacing of 10 km. In a span of a few years, second generation lightwave systems operating near 1.3 μm were developed. The advantages of operating at this wavelength could increase repeater spacing. It was also found that the optical fiber loss is below 1 dB/km and it exhibits minimum dispersion near 1.3 μm wavelength region [1]. Second generation system was developed using InGaAsP lasers and detector, but the bit rate was limited to below 100 Mbit/s due to the dispersion in multimode fibers. With the introduction of single mode fiber in the mid 80s, this limitation was overcome. By 1987, second generation light wave systems were operating at a bit rate up to 1.7 Gb/s with a repeater spacing of 50 km. However, it was found that second generation systems were limited by the fiber loss at 1.3 μm, thus in order to achieve a faster data rate or longer distance it must operate near 1.55 μm where the loss of silica fibers is minimum. However, there was another problem with conventional InGaAsP semiconductor lasers, as they could not be used because of pulse spreading which occurs as a result of simultaneous oscillation of several longitudinal modes. Two methods were introduced to cope with this dispersion problem. The first approach was the use of dispersion shifted fibers, which are designed to have a minimum dispersion near 1.55 μm and the second approach was to limit the laser spectrum to a single longitudinal mode. In 1990, third generation 1.55 μm systems were developed using these approaches and the systems were operating at a bit rate of 2.5 Gb/s. Despite the better performance of third generation systems, they have a major drawback: the need to regenerate the signal periodically by using electronic repeaters typically spaced 60-70 km apart [1]. This problem was overcome with the advent of fiber amplifiers in the early 90s. The fourth generation systems were developed using fiber amplifiers to increase the repeater spacing and bit rate. The development of erbium doped fiber amplifier (EDFA) was a major impetus to the research on active-fiber technology in the 1.55 μm wavelength region and it had a great impact on ultra-long transmission. . Erbium doped fiber has made it possible to transmit optical signals over thousands of kilometers without electrical repeaters, simply by cascading optical amplifiers and fiber sections in a chain [4]. This technology has allowed systems to transmit data at longer distance and at a faster data rate. By 1996, it was reported in [1] that fourth generation systems were capable of transmitting over 11,300 km at a bit rate of 5 Gb/s. Although the optical amplifiers solve the loss problem, they worsen the dispersion problem since the dispersive effects accumulate over multiple amplification stages. Thus, the fiber dispersion remains in fourth generation systems while fifth generation systems are concerned with finding a solution. By the early part of the 2000s, almost every long-haul (typically between 300 and 800 km) or ultra-long-haul (typically longer than 800 km) fiber-optic transmission system uses Raman amplification. Raman amplifiers were not deployed until the late 1990s. The problem was a relatively poor efficiency of Raman amplifiers at lower signal powers. Erbium-doped fiber amplifiers required powers in the range of 1 to 10 mW, whereas Raman amplifiers required powers in the range of 1 to 5 W. Therefore, to achieve a gain of 20 dB or more required almost three orders of magnitude more pump power in Raman amplifiers [5]. Now days Optical hybrid amplifier provides high power gain. Mohammed N.Islam described that the total amplifier gain (GHybrid) is the sum of the two gains [6]: GHybrid =GEDFA +GRaman if we are using RAMAN-EDFA hybrid amplifier. Recent efforts have been directed towards realizing greater capacity utilization of fiber systems by multiplexing a large number of wavelengths. These systems are referred to as dense wavelength-division multiplexing (DWDM) system. This system aimed at reducing the wavelength separation of 0.8 nm which is currently in operation to less than 0.5 nm. Controlling the wavelength stability and development of wavelength de-multiplexing devices are critical to these efforts.

Hidenori Taga et al. [7], discussed that until the optical amplifiers were developed, only the short distance (up to a few tens kilometers) WDM system was in focus, because the optical repeaters for the WDM transmission were considered to be not practical. The advent of the optical amplifiers made it possible to construct the long distance. There are two types of OAs which are used in communication system; semiconductor optical amplifiers (SOAs) and doped fiber amplifiers (DFAs).

R. Boudreau et al. [8] reproducibly demonstrated a simple, high-gain (19 to 21 dB) semiconductor optical amplifier package in which stable, reworkable fiber attachment is achieved by soldering. A two temperature- zone package, with thermoelectric coolers, is used to solder each fiber without affecting the other.

T. Toyonaka et al. [9] proposed the use of a high NA aspheric lens for coupling optics, and have fabricated a high-gain polarization-insensitive SOA module. A coupling loss as low as 3dB/facet, a net gain of 22dB, and a polarization sensitivity of less than 0.5 dB are also demonstrated.

Jay M. Wiesenfeld et al. [10] has been translated data at 10 Gb/s from an input signal wavelength to another wavelength, either longer or shorter, using gain compression in a 1.5-pm semiconductor optical amplifier for wavelength conversion. They are described that using moderate input powers; wavelength conversion is achieved over a 17 nm (2 THz) range, with 0.7-3 dB power penalties.

Surinder Singh and R.S. Kaler [11] investigated post, pre- and symmetrical power compensation methods for different positions of the SOA in fiber link. This research is 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. The effect of increase in signal input power for the three power compensation methods is compared in terms of eye diagram, bit error rate, eye closure penalty and output received power.

D.N. Payne [12] at the University of Southampton, developed a technology of rare earth ions deposition in single-mode silica fibers and the first EDFA was reported in 1987. They are observed that Gains of up to 28 dB have been attained in the important wavelength region of 1.54 µm.

Bergano et al. [13] successfully demonstrated transmission of 640 Gb/s over 7200 km by using a recirculating loop. Results from this paper indicate that 5 Gbit/s all-optical EDFA transmission systems are capable of achieving transoceanic distances at very low error rates.

Vareille et al. [14] demonstrated the transmission capacity of 340 Gb/s over 6380 km on a straight-line test bed. They are fully representative of systems using 32 channels plus 2 additional wavelengths used for N+ 1 network protection schemes

II. SIMULATION SET UP

To investigate the performance of the hybrid amplifiers, at sixteen, thirty two or sixty four user transmitters are used at a speed of 10 Gbps speed as shown in fig 1. The signals from data source and laser are fed to the external Mach-Zehnder modulator, where the input signals from data source are modulated through a carrier optical output signal is transmitted. These signals are transmitted over spliter to which the optical power meter and optical spectrum analyser is attached. The optical splitter splits the optical signals into two or more outputs. Further a compound component is placed which consists of Raman-EDFA, Raman-SOA, SOA-EDFA, and Raman-EDFA. We can also choose any other hybrid amplifiers according to the requirements. Again then optical splitter is attached to which optical power meter and optical spectrum analyser are attached. Later, the receiver is attached which is used to detect all signals and converted into electrical signal. Different types of optical amplifiers are applied at different channels. The optical signal is transmitted and measured over different distance using different number of channels. The different parameters like quality factor, Ber, eye opening, jitter are calculated at different channels and best of it is calculated at various channels. Optical signals are amplified using EDFA amplifier. The signal power is measured by power meter and optical probe. The modulated signal is converted into original signal with the help of PIN photodiode and filters. A compound receiver is used to detect all the signals and converts these into electrical signals. Also a power meter can be attached to achieve the power at the receiver end which is needed for the project.

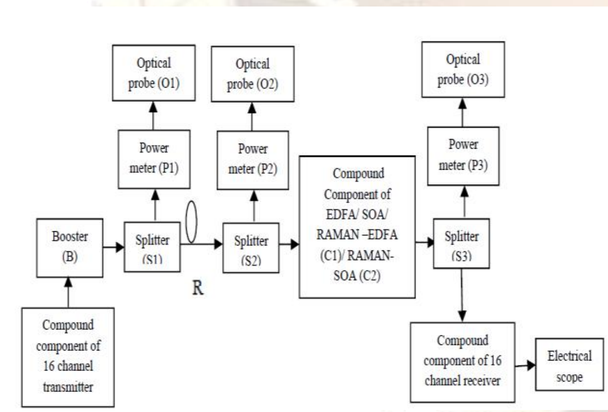

Fig.1 Block Diagram of simulation setup

III. RESULTS AND DISCUSSIONS

Performance of different amplifiers EDFA, SOA are compared at different distance. The optical signal is applied to different optical amplifier in order to observe the performance of different amplifiers (EDFA, SOA) the output power versus transmission distance graph are shown for different dispersion. These graphs show that as we increase the transmission distance from 75 to 180 km, the output power decreases simultaneously. The variation in output power from different optical amplifiers at dispersion D=2 ps/nm/km is 6.966 to 6.726 dBm for EDFA, 8.038 to -7.184 dBm for SOA.

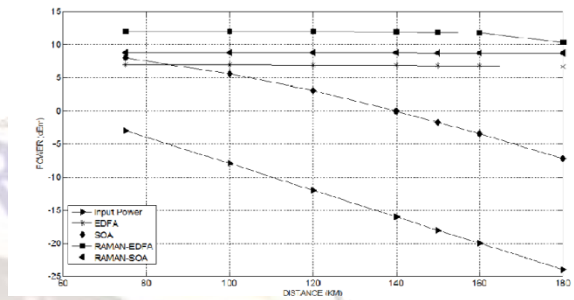

Fig.2(a)

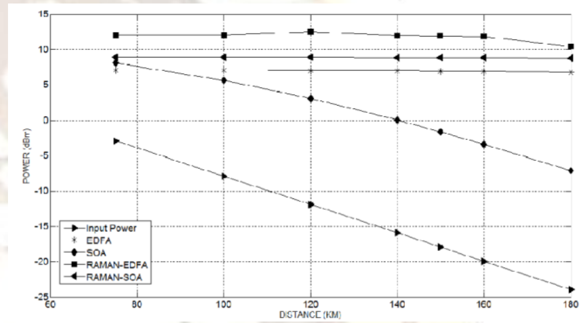

Fig.2(b)

Figure : Power vs Distance for 2(a) D=2 ps/nm/km 2(b) D=4 ps/nm/km

The output power results from different optical amplifiers at dispersion D=2, 4 ps/nm/km are shown in figure. The input of optical amplifiers is -2.980 to -23.954 dBm for D=2ps/nm/km and -2.911 to -23.966 dBm is for D=4 ps/nm/km corresponding to different transmission distance. The optical output power for dispersion 2 ps/nm/km and 4 ps/nm/km is 6.983 dBm and 7.046 dBm respectively.

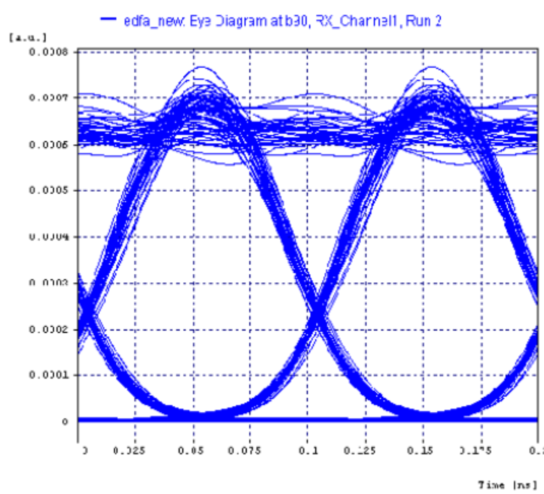

Fig.3

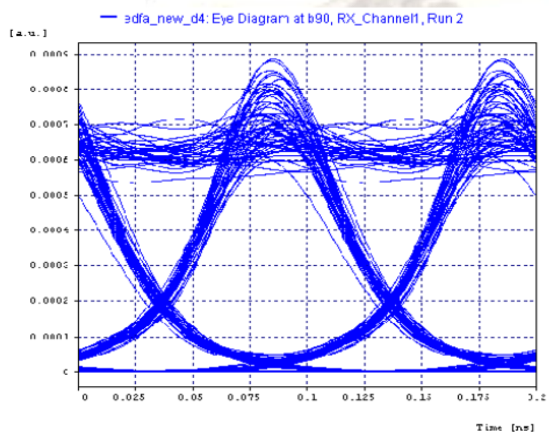

Fig.4

Figure: Eye diagram for EDFA at 100 km for (a) D=2 ps/nm/km (b) D=4 ps/nm/km

Eye diagram of signal after EDFA at 100 km distance with 2 ps/nm/km and 4 ps/nm/km is shown in figure 3.11. The eye opening for dispersion 2 ps/nm/km and 4 ps/nm/km is 5.56×10-4 and 4.41×10-4 respectively.

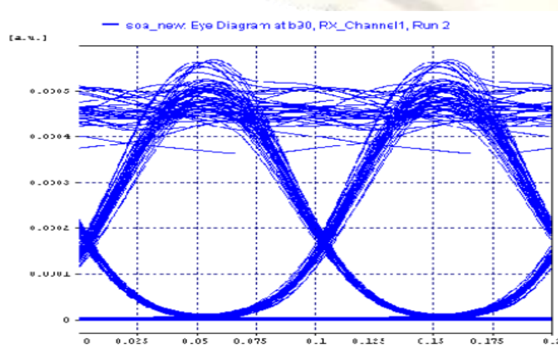

Fig. 3

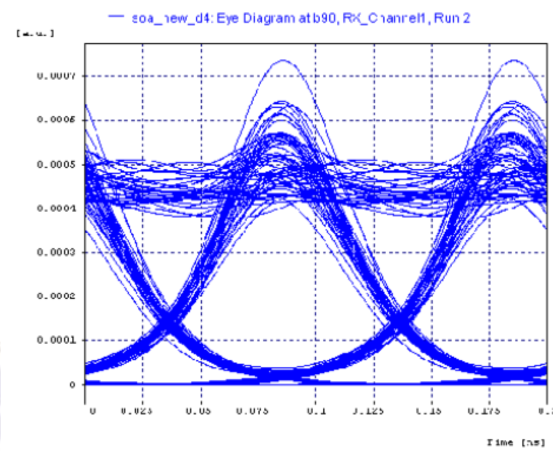

Fig.4

Figure: Eye diagram for SOA at 100 km for (a) D=2 ps/nm/km (b) D=4 ps/nm/km

IV.CONCLUSION

The optical amplifiers design models were successfully designed and implemented into OptSim. The main motivation of this work is to optimize the optical amplifiers for different dispersion and transmission distance. The performance of optical amplifiers was evaluated using the eye patterns, BER measurement, eye opening and Q factor. The simulation results shows behavior EDFA, SOA in terms of eye and power diagrams.

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