Analysis of 64 × 10 Gbps Dense Wavelength Division Multiplexing System Using Optimized RAMAN-EDFA Hybrid Optical Amplifier

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***Abstract*—In this paper, the performance of 64 × 10 Gbps dense wavelength division multiplexing system using RAMAN-EDFA hybrid optical amplifier with 0.8 nm channel spacing has been demonstrated and the effect of Input signal power and bit rate has been investigated. The results have been carried out by evaluating the value of quality factor, BER and average opening of eye. It is found that using RAMAN-EDFA hybrid optical amplifier; the signal can be transmitted up to transmission distance of 135 km at low signal input power of-20 dBm with acceptable BER and Q-factor respectively. In addition, the system provides acceptable performance up to 165 Km and 200 Km with the signal input power of-10 dBm and 0 dBm.**

Keywords: Bit Error Rate, DWDM, RAMAN-EDFA

I. INTRODUCTION

The demand for broadcast over the global telecommunication network will continue to rise at an exponential rate and fiber optical system will be able to meet up the challenge. Optical fibers are considered as the main wire line physical medium for transmitting multimedia communication applications that require large amount of bandwidth [1]. Current efforts have been aimed at realization of greater capacity utilization of optical networks by multiplexing huge number of channels. These systems are referred to as dense wavelength-division multiplexing system. Dense WDM technology is recognized for its increase in transmission capability in optical communication system [2]. The combination of a multiple wavelengths on a single fiber allows for sharing of network elements such as amplifiers resulting in considerable cost savings [3]. The advancement in the fiber optic networks has been promoted by development of efficient optical amplifiers which eradicate the need of costly Optical-Electrical-optical conversions [4]. To extend the bandwidth and reach in optical communication system, the amplifiers having broadband and low-noise properties at reasonable cost are required. The high power conversion efficiency of erbium-doped fiber amplifiers [5] and broadband tunability combined with low-noise properties of Raman amplifiers [6] are employed in hybrid amplifier configurations to achieve better performance in WDM networks. The Hybrid amplifiers have wide gain bandwidth, more flat gain profile and high power gain which makes it advantageous over the conventional amplifiers [7].

Ju Han Lee *et al*. [8] investigated a new scheme of the dispersion-compensating Raman/EDFA hybrid amplifier recycling residual Raman pump for enhancement of overall power conversion efficiency. The significant improvement of gain of signal and gain bandwidth by 15 dB and 20 nm, compared to the performance of the Raman only amplifier was achieved by using this proposed scheme.

Singh *et al*. [9] evaluated the symmetrical, pre and post power compensation schemes for a dissimilar position of hybrid optical amplifier (RAMAN–EDFA) in an optical link. It was observed that the post power compensation scheme is better than symmetrical and pre power compensation schemes. Also the post power compensation scheme with −15 dBm signal input provides least BER of 10−40 and output power of 12 dBm.

R.S. Kaler [10] evaluated that the hybrid optical amplifier provides better performance when the optimized parameters are used. Hybrid optical amplifier (Raman-EDFA) had been optimized using different optimized parameter such as O/P power for fixed output power EDFA, noise figure and Raman pump, pump power, Raman fiber length for Raman amplifier. Further he found the maximum single span length using optimized hybrid optical amplifier. It was shown that using optimized hybrid optical amplifier, the dispersions at 2, 4, 8, and 16 ps/nm/km achieves 150, 150, 120 and 70 km of single span length with the acceptable BER.

Jian-guo Yuan *et al*. [11] introduced the configuration of the hybrid amplifier (Raman Amplifier: RA + Erbium-Doped Fiber Amplifiers: EDFA) and analyzed the restriction conditions of its optimum design. The ASE noise and Rayleigh noise in Raman Amplifier (RA) as well as their influences on the Signal Noise Ratio (SNR) of the receiver had been analyzed in depth. Furthermore, the influences which result from these noises on the performances of the optimum design for the hybrid amplifier (RA + EDFA) had thoroughly been researched.

The results presented in [9] for RAMAN-EDFA hybrid optical amplifier is carried out for a single channel. In this paper, we extended the previous work by increasing the number of channels with an improved power level and increase in maximum single span distance.

The paper is prepared in four sections. In Section 2, the system model is described. The simulation results have been calculated for the different input signal power and bit rates in section 3 and finally in Section 4, the conclusions are made.

II. Simulation Setup

The system model of 64 channel DWDM transmission system using RAMAN-EDFA hybrid optical amplifier with NRZ encoding technique and 0.8 nm interval is shown in fig. 1. An optical transmission link consists of three sections i.e. transmitter, optical amplifier and receiver. At the transmitting side, 64 channels are transmitted operating at its own frequency in range from 189.15 THz to 195.45 THz. Every transmitter consists of electrical driver, data source, laser source and external MZ modulator. The signal of 10 Gbps with pseudo random sequence is generated by the data source. Electrical driver generates Non Return to Zero rectangular type data format with a signal dynamics i.e. low level −2.5 and high level +2.5. The external MZ modulator receives the signals from data source and laser. The combiner is used to combine the all modulated optical signals and these signals are boosted by booster and fed into the optical fiber through an optical splitter. The optical splitters are used for the measurement of the optical power and to analyze optical spectrum the transmission link. The optical signals pre-amplified by booster are transmitted over DS anomalous fiber having reference frequency of 193.414 THz and attenuation of 0.2 dB/km.

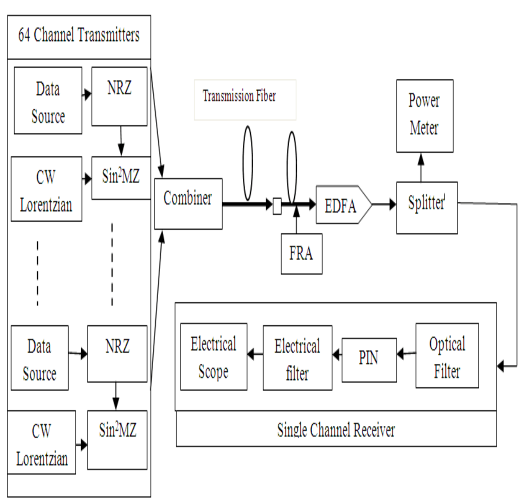

Fig. 1 System Model

Different components have different operational parameters. The type of EDFA used for amplification is fixed output power EDFA and its parameters are flat gain shape, fixed output power of 35mW and noise figure of 4.5 dB. The optimized parameters of Raman fiber are shown in Table 1.

TABLE 1 OPTIMIZED PARAMETERS OF RAMAN FIBER

Parameter	Value
Raman fiber length	10 Km
Operating temperature	300 K
Pump power	500mW
Pump Wavelength	1453 nm
Pump attenuation	0.2dB/km

The Optical raised cosine filter, PIN photodiode and Electrical raised cosine filter constitutes a single receiver. Raised Cosine Optical filter has band pass filter synthesis, 0.2 raised cosine roll off, 1 as raised cosine exponent and 40 GHz BW. The optical signal is converted to electrical signal using PIN photodiode, the Quantum efficiency of which is 0.7 A/W and responsivity is 0.87. Electrical raised cosine filter at the receiver side has bandwidth 8 GHz. The eye diagram is obtained from the Electrical Scope. The values of Quality factor, average opening of eye and Bit Error Rate can be analyzed from the eye diagram.

III. Results and Discussions

To evaluate the system performance, the eye diagram is analyzed for the first channel (189.15 THz) received at the receiver. Performance of 640 Gbps (64×10) dense Wavelength multiplexed system using RAMAN-EDFA hybrid optical amplifier is investigated by varying the distance from 50 to 250 Km. For different signal input power, the Q factor vs. transmission distance graph is as shown in Fig. 2. The quality of the received signal decreases as we increase the length of the fiber from 50 to 250 Km. The Quality factor varies as 21.14 to 6.02 dB for-20 dBm, 22.81 to 6.02 dB for -10 dBm and 24.74 to 6.02 dB for 0 signal input power. The acceptable Q factor is obtained up to 135 km transmission length for -20 dBm signal input power. For -10 dBm & 0d Bm signal input power acceptable quality factor is achieved up to 165km and 200km transmission length without dispersion compensation methods. This shows better results over [9] where the transmission length of 126 km was achieved with one channel using post power compensation scheme.

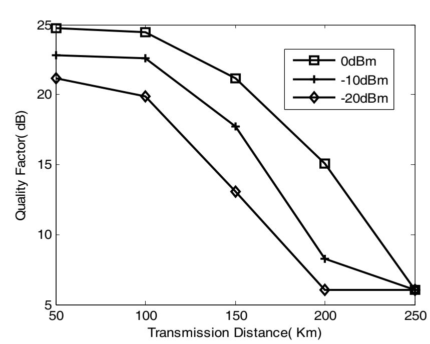

Fig. 2 Quality Factor vs. Transmission Distance for different Signal Input Power

Figure 3 reveals the plot of Bit Error Rate vs. transmission distance for different signal input power. The variation in BER from different input signal powers are 4.25 e -30 to 0.0227 for -20 dBm, 1.19 e -40 to 0.0227 for -10 dBm and 1 e -40 to 0.0227 for 0 input signal power. It is found that with an increase in the signal input power at the optical fiber link, the bit error Rate decreases.

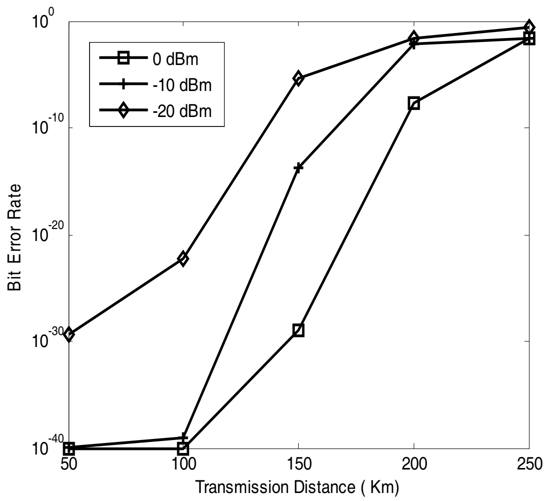

Fig. 3 Bit Error Rate vs. Transmission Distance for different Input Signal Power

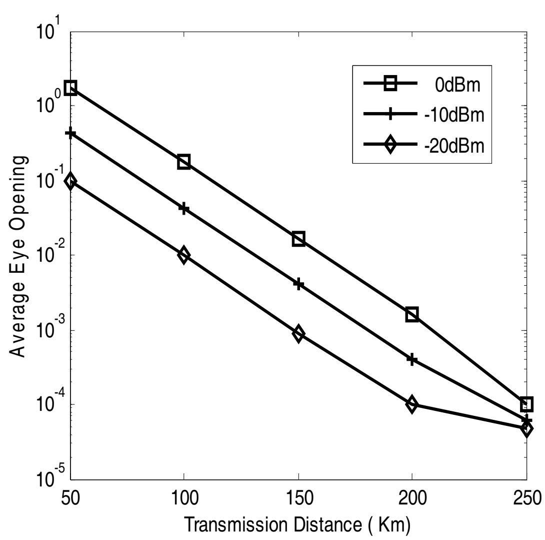

Fig. 4 Average Eye Opening vs. Transmission Distance for different Signal Input Power

The average eye opening from different input signal powers vs. transmission distance is shown in Fig. 4. It is evident that large opening of eye means less Bit Error Rate and high quality communication. It is found that average eye opening is decreasing, as the transmission length is increasing from 50 to 250 km. The average eye opening varies as is 0.0981 to 4.82 e -05 for -20 dBm, 0.4291 to 6.14 e -005 for -10 dBm and 1.7148 to 0.0001 for 0 dBm input signal power.

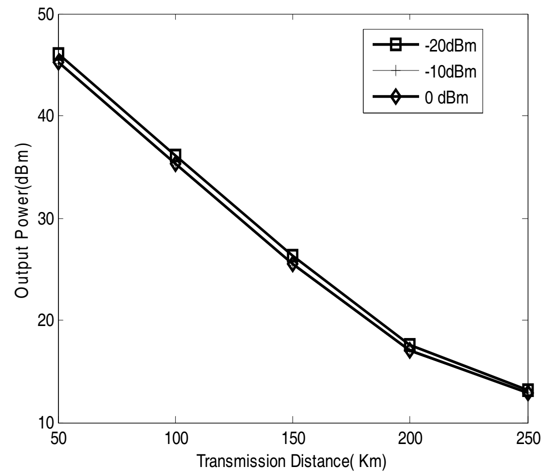

Fig. 5 Output Power vs. Transmission Distance for different signal input power

Figure 5 shows the output power vs. transmission distance. For-20dBm signal input power, the system shows the output power of 33.423 dBm at acceptable transmission distance of 135 Km which is an improvement over [9] in which the output power of 12dBm was obtained with the input signal power of-15 dBm at 126 Km with only one channel at input.

Further the performance of DWDM system was evaluated by varying the bit rates from 5 to 15 Gbps & has been evaluated on the basis of value of Q factor, Bit Error Rate and Average eye opening. The Quality Factor vs. transmission distance graph for different bit rates is shown in Fig. 6

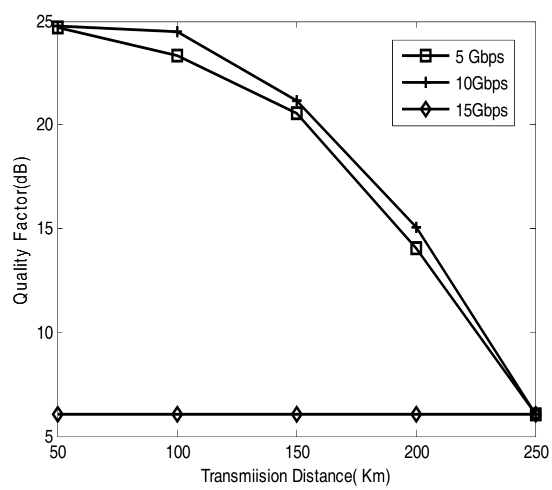

Fig. 6 Quality Factor vs. Transmission Distance at different Bit Rates

Figures 7 and 8 show the Bit Error rate and average eye opening vs. transmission distance for three different bit rates. The simulation results show that worst results are obtained for the bit rate of 15 Gbps.

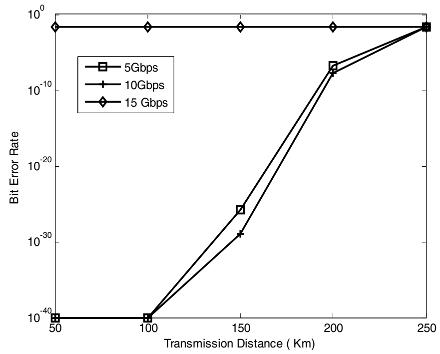

Fig. 7 Bit Error Rate vs. Transmission Distance at different Bit Rates

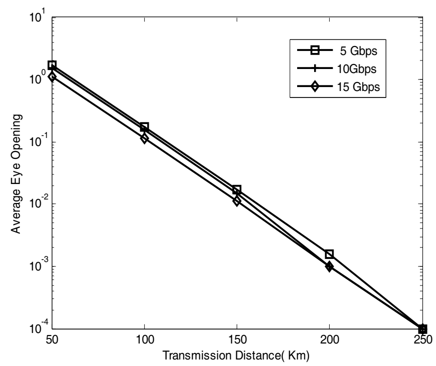

Fig. 8 Average Eye Opening vs. Transmission Distance at different Bit Rates

The eye diagram of signal after RAMAN-EDFA hybrid optical amplifier at 135 km distance with signal input power of-20dBm and bit Rate of 10Gbps is shown in Fig. 9

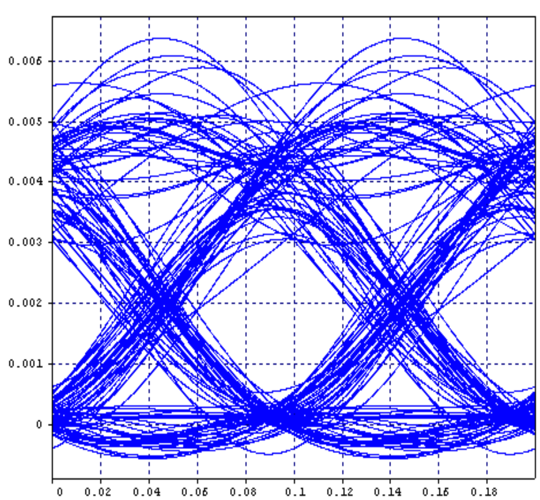

Fig. 9 Eye Diagram for RAMAN-EDFA at 135 Km with Signal Input Power of-20 dBm and Bit Rate of 10Gbps

IV. CONCLUSION

The 64 channel Dense Wavelength Division Multiplexing system at 10Gbps and 0.8 nm interval has been investigated with the RAMAN-EDFA hybrid optical amplifier. The performance was calculated for different bit rates and input signal power & has been evaluated on the basis of value of Q Factor, output power level, average eye opening and BER. The worst results are obtained at the bit rate of 15Gbps. Further, it is observed that the RAMAN-EDFA hybrid optical amplifier provides acceptable quality factor (15.57dB) and bit error rate (1.04e-09) up to 135 km transmission distance for-20dBm signal input power with without any dispersion compensation methods.

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