32 x 10 and 64 × 10 Gb/s transmission using hybrid Raman-Erbium doped optical amplifiers

Shveta Singh[1], M.L.Sharma[2]
Department of Electronics and Communication,
B.G.I.E.T, Sangrur, India

Ramandeep Kaur[3],
Department of Electronics and Communication, Thapar University, Patiala, India

***Abstract*— We have successfully demonstrated a long-haul transmission of 32 × 10 Gbit/s and 64 × 10 Gbit/s over single-mode fiber of 650 km and 530 km respectively by using RAMAN-EDFA hybrid optical amplifier as inline and preamplifier amplifiers. The measured Q-factors and BER of the 32 and 64 channels after 650 and 530 km respectively (16.99–17 dB) and (10^{-13}) were higher than the standard acceptable value, which offers feasibility of the hybrid amplifiers including EDFA optical amplifiers for the long-haul transmission.**

Keywords- HOA; RAMAN; EDFA; BER; Q-FACTOR; EYE-OPENING; DISPERSION; TRANSMISSION DISTANCE; WDM and DWDM.

I. INTRODUCTION

Wavelength division multiplexing (WDM) is basically frequency division multiplexing in the optical frequency domain, where on a single optical fiber there are multiple communication channels at different wavelengths [1]. A WDM system uses a multiplexer at the transmitter to join the signals together and a demultiplexer at the receiver to split them apart. By using WDM and optical amplifiers, they can accommodate several generations of technology development in their optical infrastructure [2]. Optical gain depends on the frequency of the incident signal and also on the local beam intensity. Dense wavelength division multiplexing (DWDM) is a technology that puts data from different sources together on an optical fiber, with each signal carried at the same time on its own separate light wavelength [3]. Optical amplifiers have several advantages over regenerators. Optical amplifiers can be more easily upgraded to a higher bit rate. In an optical communication system, as the optical signals from the transmitter propagate through optical fiber are attenuated by it and losses are added by other optical components, such as multiplexers and couplers which causes the signal to become too weak to be detected. Before this the signal strength has to be regenerated [4]. Most optical amplifiers amplify incident light through stimulated emission, its main ingredient is the optical gain realized when the amplifier is pumped to achieve population inversion. The optical gain, in general, depends not only on the frequency of the incident signal, but also on the local beam intensity at any point inside the amplifier [5]. To understand how optical amplification works, the mutual or reciprocal action of electromagnetic radiation with matter must be understood [6]. Optical amplification uses the principle of stimulated emission same as used in a laser. Optical amplifiers can be divided into two basic classes: optical fiber amplifiers (OFAs) and semiconductor optical amplifiers (SOAs) [1]. An amplifier can boost the (average) power of a laser output to higher levels. It can generate extremely high peak powers, particularly in ultra short pulses, if the stored energy is extracted within a short time. It can amplify weak signals before photo detection, and thus reduce the detection noise, unless the added amplifier noise is large. In long fiber-optic links for optical fiber communications, the optical power level has to be raised between long sections of fiber before the information is lost in the noise [7]. The combination of an erbium-doped fiber amplifier (EDFA) and a fiber Raman amplifier (FRA or RA) is called a hybrid amplifier (HA), the RAMAN-EDFA. Hybrid amplifier provides high power gain. Raman amplifier is better because it provides distributed amplification within the fiber. Distributed amplification uses the transmission fiber as the gain medium by multiplexing a pump wavelength and signal wavelength. It increases the length of spans between the amplifiers and regeneration sites. So this provides amplification over wider and different regions [8]. HYBRID Raman/erbium-doped fiber amplifiers (HFAs) are an advance technology for future. Hybrid Raman/erbium-doped fiber amplifiers are designed to maximize the long-haul transmission distance [9].

H.S. Chung *et al.* [10] have successfully demonstrated a long-haul transmission using cascaded Raman and linear optical amplifiers as inline amplifiers of 16 × 10 Gbit/s over single-mode fiber of 1040 km. Q-factors of the 16 channels after 1040 km (12.7–14.5 dB) were higher than the error-free threshold of the standard forward-error correction, which offers feasibility of the hybrid amplifiers including semiconductor optical amplifiers for the long-haul transmission.

Tetsufumi Tsuzaki *et al.* [11] have successfully developed a 64nm hybrid optical repeater amplifier for a long-distance WDM transmission system. The gain variation after 40 concatenations was reduced below 3dB with the optimal equalization techniques. Using these repeaters, transmitted 3.2Tb/s (1 60 x 20 GB/s RZ) over 1,500 km using 64nm hybrid optical repeater amplifier for a long-distance WDM transmission system.

Seung Kwan Kim *et al.* [12] describes the multiple channel amplification, using commercially available pump laser diodes and fiber components, they determined and optimized the conditions of three-wavelength Raman pumping for an amplification bandwidth of 32 nm for C-band and 34 nm for L-band using design of a hybrid amplifier composed of a distributed Raman amplifier and erbium- doped fiber amplifiers for C- and L-bands.

T.N.Nielsen *et al.* [13] has demonstrated ultra-high capacity WDM transmission systems based on either dual C- and L-band transmission, or distributed Raman amplification with aggregate capacities of more than 1 Tbls. In this paper they demonstrate a record capacity of 3.28-Tb/s by, for the first time, combining these three techniques in one system. The 3.28-Tb/s is comprised of forty 100-GHz spaced WDM channels in the C-band and forty-two 100-GHz spaced WDM channels in the L-band.

Unlike the previous work [9] with the hybrid amplifiers based on LOAs, we used RAMAN- EDFA and a variable span R of different lengths, which includes the transmission of 32 × 10 Gb/s and 64 × 10 Gb/s upto 650 and 530 km respectively using raman/edfa hybrid optical amplifiers, which offers feasibility of the hybrid amplifiers including EDFA optical amplifiers for the long-haul transmission.

This paper is divided into different sections for transmission of 32 × 10 and 64 × 10 Gb/s using hybrid raman/edfa amplifiers. In section 2, the simulation set up for the transmission of 32 and 64 channels at 10 Gb/s speed. Section 3 gives the discussion of the results observed after the simulation. And section 4 gives the conclusion of the system performance.

II. SIMULATION SETUP

In the figure shown below, 32 and 64 channels are transmitted at 10 Gb/s speed. Input signals are pre-amplified by a booster and these signals are transmitted over optical fiber of different transmission distances. The figure shows the compound component composed of RAMAN/EDFA at different distance and dispersion. This transmitter compound component consists of the data source, electrical driver, laser source and external Mach-Zehnder modulator in each transmitter section. The data source is generating signal of 10 Gb/s with pseudo random sequence. The electrical driver converts the logical input signal into an electrical signal. The CW laser sources generate the 16 laser beams at 191.9 THz to 193.4 THz with 100 GHz channel spacing. These beams have random laser phase and ideal laser noise bandwidth. The signals from data source and laser are fed to the external Mach-Zehnder modulator, where the input signals from data source is modulated through a carrier. optical output signal is transmitted over different distance for 100,100,100,90,90,90,80 km for 32 channel and 100,90,90,90,80,80 km for 64 channels at 2 ps/nm/km dispersion. Optical power meter and optical spectrum analyser with splitter are used for calculating signal power and spectrum. Receiver is used to receive 32/64 output signals and these signals are then converted into electrical signal. Optical Power meter and Optical probe with splitters are used for measuring the signal power at different levels. 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 signals and converts these into electrical fo R is the variable span length of 100, 100, 100, 90, 90, 90, 80 km for 32 channel and 100, 90, 90, 90, 80, 80 km for 64 channels for long hual transmission of optical fiber using raman/edfa Optical amplifiers.

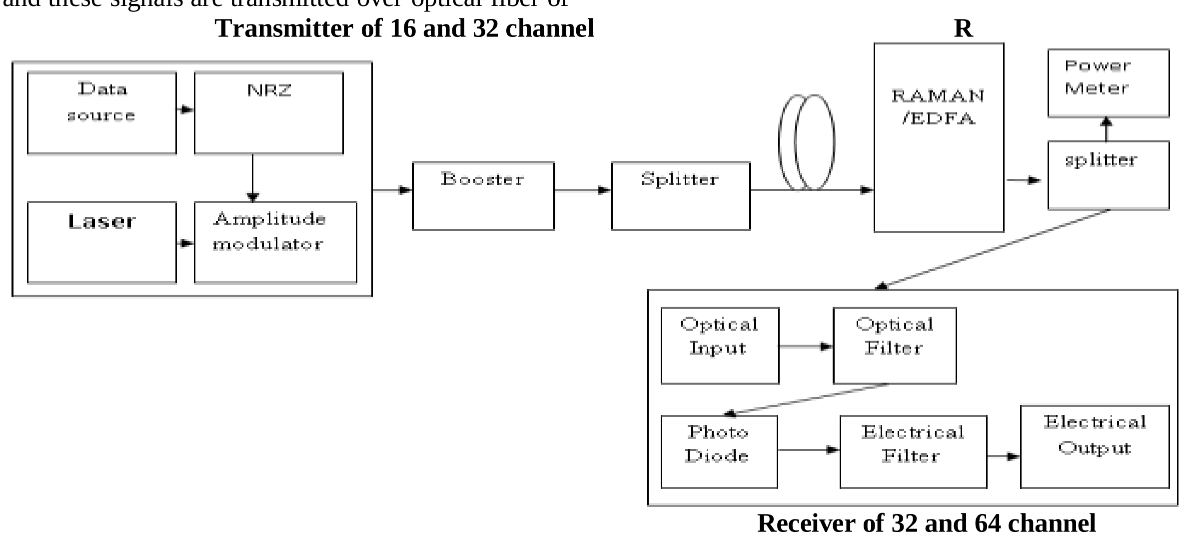

Figure 1: Block Diagram of Simulation Setup

III. RESULTS AND DISCUSSIONS

In the previous section, we have discussed various components used in the simulation setup. Using this setup we are taking measurements of BER, Q-factor, eye closure and output power at 10Gbps with respect to the length. The result discussed below gives optimized parameters of hybrid optical amplifiers (RAMAN-EDFA). The optimization is done on the basis of BER, Q-factor, eye closure and output power for hybrid optical amplifier by changing the transmission distance varying from 100 to 650 km and 100 to 530 km for 32 and 64 channel respectively.

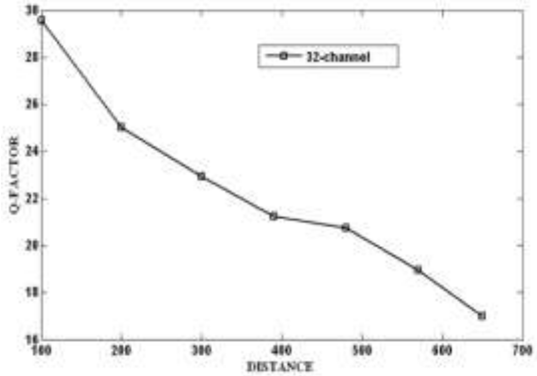

Figure 2: Quality factor vs. distance for 32 channels

In order to observe the performance of RAMAN-EDFA, the quality factor versus transmission distance are shown in figure 2.This graph shows that as we increase the transmission distance from 100 to 650 km, the quality factor decreases simultaneously. The transmission distance is varied with R (R= 100, 100, 100, 90, 90, 90, 80 km). The quality factor decreases from 29.5 to16.9 db for 32 channels.

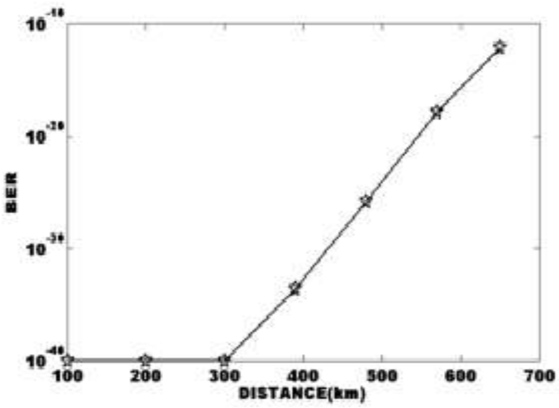

Figure 3: BER vs. distance for 32 channels.

As shown in figure 3, BER increases with distance from 10^{-40} to 10^{-13}. The acceptable bit error rate (BER) for optical transmission is 1×10^{-10}. The BER versus transmission distance for different dispersion is shown in figure. It is observed that by increasing the transmission distance from 100 to 650 km, BER is also increasing.

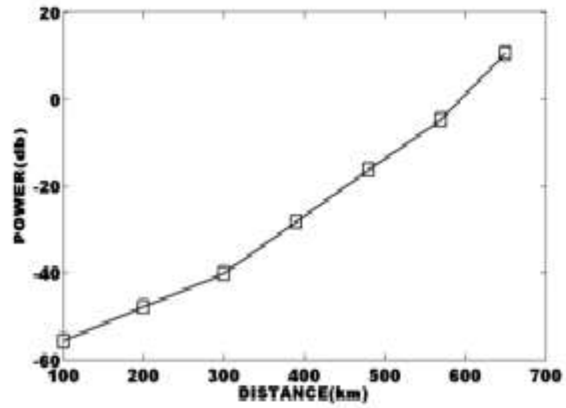

Figure 4: power vs. distance for 32 channels

The power vs. distance is shown in figure 4, Power increases with distance from -55.525 to 10.658 db for 32 channel and quality factor decreases from 29.5 to 16.9 db. The acceptable power for optical transmission is 10 db. It is observed that by increasing distance from 100 to 650 km, power is also increasing.

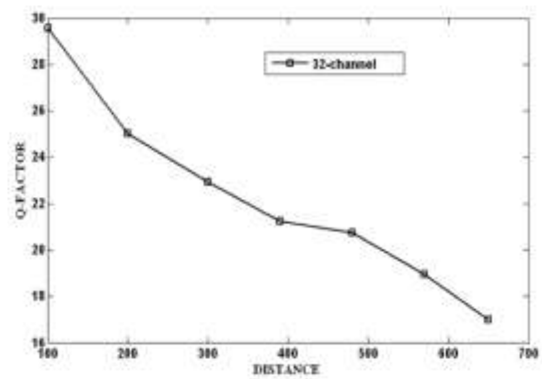

Figure 5: Q-factor vs. distance for 64 channels Figure 7: Power vs. distance for 64 channels

In order to observe the performance of RAMAN-EDFA, the quality factor versus transmission distance are shown in figure 5.This graph shows that as we increase the transmission distance from 100 to 530 km, the quality factor decreases simultaneously. The quality factor decreases from 28 to 17db for 64 channels.

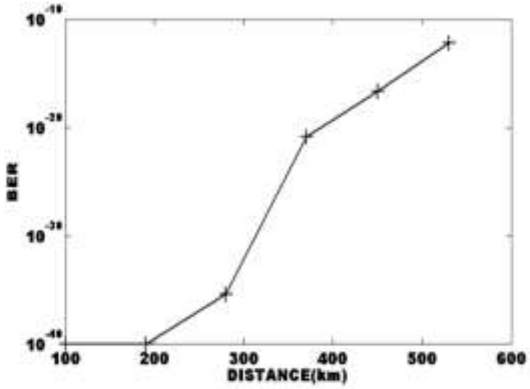

Figure 6: BER vs. distance for 64 channels

As shown in figure 6 BER increases with distance from 10^{-40} to 10^{-13}. The acceptable bit error rate (BER) for optical transmission is 1×10^{-10}. The BER versus transmission distance for different dispersion is shown in figure. It is observed that by increasing the transmission distance from 100 to 530 km, BER is also increasing.

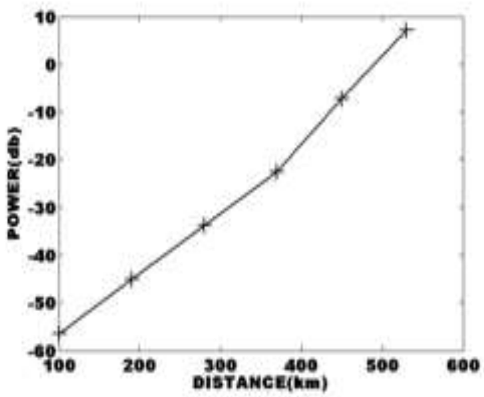

Figure 7: Power vs. distance for 64 channels

As shown in figure 7, Power vs transmission distance from 100 to 530 km, Power increases with distance from -56.415 to 7.178 db for 64 channel and quality factor decreases from 28 to 17 db. The acceptable power for optical transmission is 10 db. It is observed that by increasing distance from 100 to 650 km, power is also increasing. The performance of Raman amplification depends on the properties of the transmission fibers used. The Raman gain efficiency, determining how much Raman gain can be obtained from a given amount of pump power, depends on a number of factors, including the Raman effective area, the composition of the fiber, and the pump and signal wavelengths.

The output power characteristics of the HA are determined by the EDFA. EDFA's offer available output powers of up to 30dBm, the main determining factor is the pump power. Raman amplifiers are broad-band and wavelength agnostic. Raman amplifiers can be distributed, lumped or discrete, or hybrid. Also, in Raman amplifiers the amplification and dispersion compensation can be combined in the same fiber length.

For high channel count systems, as will be deployed in the next few years, Raman amplifiers' efficiency actually exceeds even 1480-nm pumped -band EDFAs. Consequently, Raman amplifiers should see a wide range of deployment in the next few years.

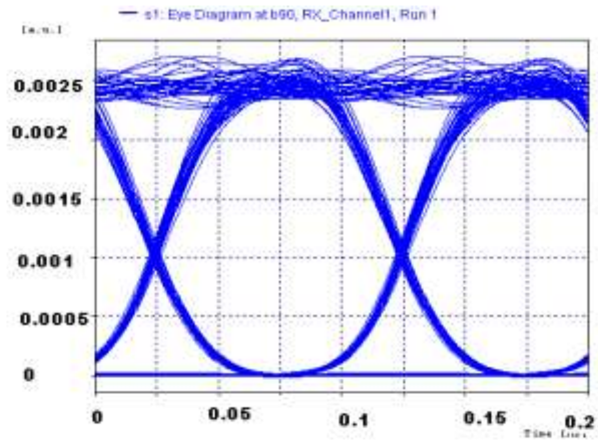

Figure 8: Eye Diagram for RAMAN/EDFA at 100 km for 32 channel

As shown in figure 8, Eye diagram of signal after RAMAN/EDFA at 32 channels with 100 km distance is shown in figure 8.

The eye opening for 100 km is 0.002316, quality factor decreases from 29.5 to 16.9 db and BER is also increasing.

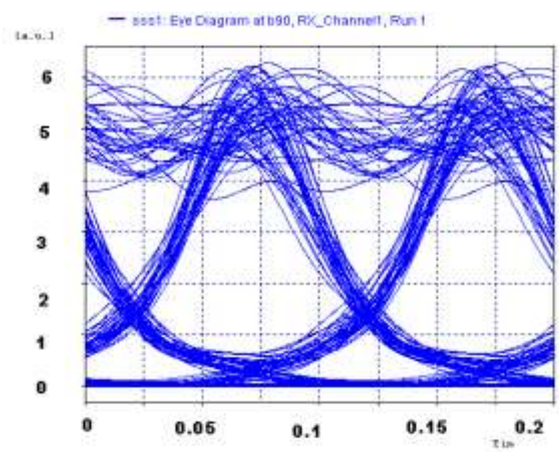

Figure 9: Eye Diagram for RAMAN/EDFA at 650 km at 32 channel

Eye diagram of signal after RAMAN/EDFA at 32 channels with 650 km distance is shown in figure 9.

The eye opening for 650 km is 3.18696, quality factor decreases from 29.5 to 16.9 db and BER is also increasing.

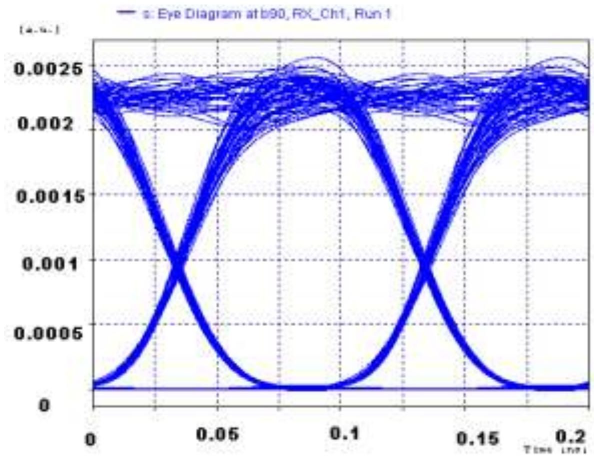

Figure 10: Eye Diagram for RAMAN/EDFA for 64 channel at 100 km

It is observed from the simulation result from the figure 10, that maximum eye opening is obtained from RAMANEDFA at 64 channel is 0.00206 and 2.25773 at 100 km and 530 km transmission distance respectively.

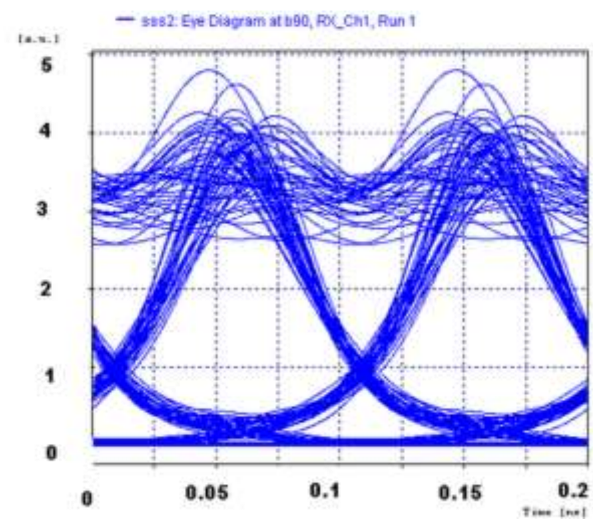

Figure 11: Eye Diagram for RAMAN/EDFA for 64 channel at 530 km

As shown in figure 11, it is observed from the simulation result from the figure 10, that maximum eye opening is obtained from RAMANEDFA at 64 channel is and 2.25773 at 530 km transmission distance.

IV. CONCLUSION

In this Paper, we have successfully demonstrated long-haul WDM transmissions using RAMAN/EDFA as the inline amplifiers.The results offered the feasibility of the Raman/EDFA as inline amplifiers for long distances of 650 and 530 km. We have been observed that before 650 and 530 km, we have an acceptable BER, Q-factor, Power and eye-opening.

After that we observed that the quality factor and ber increases. The performance of optical amplifiers was evaluated using the eye patterns, BER measurement, eye opening, Q factor and power. The simulation results show that RAMAN-EDFA has quality factor of 16.99 db, BER of 7.01×10^{-13}, Eye-Opening of 4.928 and power of 10.65 at 650 km for 32 channel at 10 Gb/s and Quality factor of 17 db, BER of 6.5×10^{-13}, power of 7.17 at 530 km for 64 channel at 10 Gb/s.

The output power, Q factor and eye opening are decreasing. Also there is an increment in BER after 650 Km and 530 km for 32 and 64 channels respectively.

REFERENCES

[1] K. H. Liu, ‘IP over WDM’, New York: John Wiley and Sons, (2002), Pages 147-151.

[2] Biswanath Mukherjee, ‘Optical WDM Networks’, Springer, New York, (2006).

[3] P.E. Green, “Fiber-Optic Networks”, Prentice-Hall, Cam- bridge, MA, (1992).

[4] Rajiv Ramaswani and Kumar N. Sivarajan, “Introduction to Optical Networks”, 2nd Edition, Pages 151-153.

[5] G.P. Agrawal, “Fiber Optic Communication Systems”, John Wiley and Sons, New York, (1997), Pages 226-251.

[6] H Ghafouri-Shiraz, “Semiconductor Laser & Amplifiers”, Imperial College Press, London, Pages-15.

[7] P.Urquhart (ed.), “Advances in optical amplifiers”, an open-access book from In Tech, (2011).

[8] Simranjit singh, “Performance Evolution of Hybrid Optical Amplifiers for WDM Systems”, ISTE sponsored IDEA, Pages-7.

[9] A. Carena, “On the Optimization of Hybrid Raman/Erbium-Doped Fiber Amplifiers”, (2001), V13, pages 1170-1172.

[10] H.S. Chung, J.Han, S.H. Chang, K. Kim. “A Raman plus linear optical amplifier as an inline amplifier in a long-haul transmission of 16 channels × 10 Gbit/s over single-mode fiber of 1040 km”, (2005), V244, pages 141-145.

[11] Tetsufumi Tsuzaki, Michiko Harumoto, Motoki Kakui, Kozo Fujii, “3.2 Tb/s - 1,500 km WDM transmission experiment using 64nm hybrid repeater amplifiers”,(2000), V4, Pages 239-241.

[12] Seung Kwan Kim, Sun Hyok Chang, Jin Soo Han, and Moo Jung Chu, “Design of Hybrid Optical Amplifiers for High Capacity Optical Transmission” (2002), V24, Pages 81-96.

[13] T.N.Nielsen, A.J.Stentz, K.Rottwitt, D.S.Vengsarkar, “3.28-Tbh (82~40Gbht) transmission over 3x100 km non zero dispersion fiber using dual C-and L-band hybrid Raman/Erbium-doped inline amplifiers”, (2000).