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Evaluation of 160*10 Gbps Single & Hybrid Optical Amplifiers at 0.1 mw using EDFA-RAMAN-SOA

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***Abstract**: In this paper, single and hybrid amplifier configurations are implemented with FRA, SOA and EDFA amplifiersfor 160 channel DWDM systems at 10 Gbps& 25 GHz frequency spacing for L-band. These configurations are transmitted and measured over different distances for 40, 80, 120, 160, 200 and 240 km. The performance of single and hybrid optical amplifiers evaluated in terms of gain, output power, BER, eye height and Q factor. Among these setupsSOA-RAMAN-EDFA performed better than other optical amplifiers at all over the distance. It provides the highest output gain (53.06 to 50.84 dB), high output power (39.91 to 37.7 dBm), least bit error rate (-37.66 to -10.62 log of BER), Q factor (12.12 to 9) and good eye height (12.98 to 5.54 a.u.)for different transmission distance ranging from 40 to 240 km. These are all setups are arrangedwithout using any gain-flattening technique and receiver filters.*
***Keywords**-FRA, EDFA, SOA, DWDM, Transmission Distance,gain, Output Power, BER, Eye Height, Q factor.*

I. Introduction

The high speed transmission over the global telecommunication network without repeaters will continue to grow at an exponential rate and only optical fiber amplifiers will be able to meet the challenge [2]. For long-haul optical transmission systems broadband hybrid amplifiers with multi-pump Raman amplification and EDFA have been a demanding technique. There are two main reasons of using Raman amplifier first is the ability to provide gain at broad wavelength and second is to broaden the amplification bandwidth by adding more pump wavelength [3]. So, this work will target to performance comparison of single and hybrid optical amplifiers for higher transmission distance with improved power and BER for DWDM communication systems. In literature review, various techniques using number of different amplifiers with single or multiple pumping have been proposed to increase the transmission distance over the bandwidth region. Simranjitsingh et al. [1] investigated a flat-gain optical amplifier using a hybrid configuration with an Er-Yb co-doped waveguide amplifier (EYDWA) and a semiconductor optical amplifier (SOA) and show improved gain flatness without using any gain clamping and gain flattening techniques, which makes the system cost effective.Hari et al. [2] investigated the different optical amplifiers for less number of channels with large channel spacing using eye pattern, BER and Q factor and get optimized transmission distance to transmit the signal.Martini et al. [3] presented different hybrid amplifier configurations with two and three pumps to receive a flat global gain for a large bandwidth region.Bobrovs et al. [4] Compare performance of Raman-SOA and Raman- EDFA hybrid optical amplifiers in terms of the eye diagrams of detected signals and the maximum transmission distances and show that the EDFA-DRA combination will produce less distortions of the amplified signal.Lee et al. [5] compared the performance of three single pumps, Raman/EDFA hybrid amplifier recycling residual Raman pump in a cascaded EDF section located after and prior to DCF and Raman assisted EDFA with respect to gain, noise figure and BER.Cheng et al. [6] demonstrated a bismuth-based erbium-doped fiber amplifier (Bi-EDFA) that operates in both the C- and L-band regions with an intermediate broadband fiber Bragg grating sensor to improve flat gain characteristics and to reduce the noise figure. Simranjitsingh et al. [7] presented a HOA model using two stages DRA-EDFA dense wavelength division multiplexing system to minimize the gain variation without using any gain flattening technique.Hossein et al. [8] introduced an optimal wideband gain flattened hybrid amplifier with an effective optimization method called particle swarm optimization (PSO) to find the optimized parameters of the EDFA/FRA, this results in obtaining low gain spectrum variations for several transmission lengths.Optical communication is anefficient medium for transmission in long haul applications, but there are some drawbacks regarding optical fibers and components which degrade the efficiency of the fiber optic communication system. So, all the above researchers use different setups with variable parameters to provide large transmission distance, high flat gain, less noise figure, less system cost and large gain bandwidth for multiple channels. But some of them used large channel spacing, less number of channels, costly components in their systems. To remove these problems we have investigated the various single and HOAsfor

DWDM system at reduced channel spacing and high bit rate with different transmission distances. In this paper we have investigated different models of single and hybrid amplifiers(RAMAN, EDFA and SOA) to achieve better gain, output power, high Q factor, low BER with improved transmission distance without using any gain equalizers.After the introduction, simulation setup and parameters of Raman-EDFA-SOA is described in Section II. Section III covers the results of the experimental setup and conclusion gives in Section IV.

II. Simulation Setup

We used 160 channel transmitter and receiver model at 10Gbps data rate with channel spacing of 25 GHz. Each input signal is converted in electrical form by NRZ pulse generator (electrical driver) and modulated by Mach-Zehnder modulator. The amplified signals send to the channel where these signal are transmitted over Single mode fibers of different transmission distance. A transmitter compound component is built up using sixteen transmitters and multiplex ten transmitter compounds for one hundred sixty transmitters. This transmitter compound component consists of the PRBS data source, NRZ electrical driver, CW 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 160 laser beams at 186–189.975 THz with 25 GHz channel spacing. The simulations setup of EDFA, SOA and RAMAN and Hybrid Optical amplifiers using compound component at different transmission distance are shown in Fig. 1.

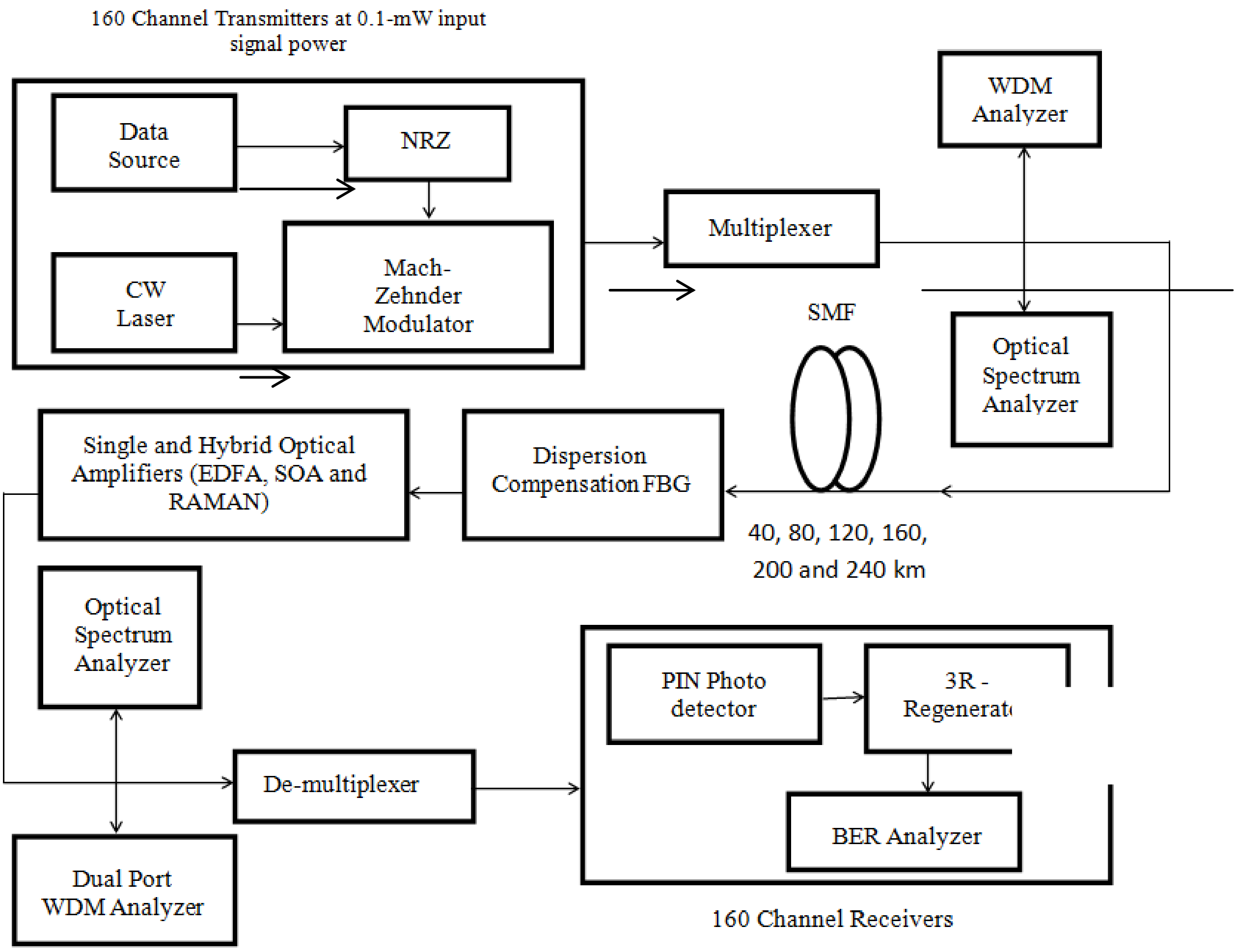

Fig. 1. Block Diagram Showing Simulation Setup for Proposed Scheme

The output optical signal of the modulator is fed to the channel. This optical signal is transmitted and measured over different distance for 40, 80, 120, 160, 200 and 240 km with nonlinearities individually. We used Dispersion fiber grating device to compensate dispersion. Then apply combination of EDFA, SOA and RAMAN as a Preamplifier to the channel. Dual port WDM analyzer, BER analyzer and Optical spectrum analyzer are used for measuring the signal power and spectrum at different levels. A compound receiver WDM Demux is used to detect all 160 signals and converts these into electrical form by using PIN photodiode. The setup is repeated for measuring the signal strength by using different amplifiers i.e. EDFA, SOA, RAMAN, EDFA-SOA, RAMAN-SOA, RAMAN-EDFA, RAMAN-SOA-EDFA and SOA-RAMAN-EDFA. Different results like gain, output power, eye height, Q-factor and BER show that SOA-RAMAN-EDFA is the most suitable amplifier in the all proposed amplifiers.

Different components have different operational parameters. The SMF optical fiber is used to transmit the optical signal. Its various parameters are shown in Table I.

Table1: Parameters For Smf Optical Fiber

Parameters	**SMF**
Reference wavelength	1550 nm
SMF length	40, 80, 120, 160, 200 and 240 km
Attenuation	0.2 dB/km
Dispersion	16 ps/nm/km
PMD coefficient	0.1 $ps/km^{0.5}$
Nonlinear refractive index (n2)	2.5e-^{020} m^2/w

The fixed gain EDFA is used to amplify the optical signal. Its various parameters are shown in Table II.

Table2: Parameters For Edfa

Operation mode	Gain control
Gain shape	Flat
Fixed small signal gain	25 dB
Noise figure	4 dB

The Fiber RAMAN amplifier is also used to enhance the output power. Its various parameters are shown in Table III.

Table3: Parameters Of Raman Fiber Amplifier

RAMAN fiber length	25 km
Attenuation	0.2 dB/km
Temperature	300 K
Pump frequency	1455.303 nm, 1498.962 nm
Pump power	650 mW, 250 mW

The travelling wave SOA amplifier is also used to enhance the transmission distance. Its various parameters are shown in Table IV.

Table4: Parameters Oftraveling Wave Soa Amplifier

Injection current	0.13 A
Length	0.0005 m
Width	3e-006 m
Height	8e-008 m
Optical confinement factor	0.3
Differential gain	2.78e-020 m^2

At the receiver side the PIN photo detector is used with a responsivity of 0.875 A/W and dark current of 0.1 nA.

III. Results

The Performance of different single and hybrid amplifiers EDFA, SOA, RAMAN, EDFA-SOA, RAMAN-SOA, RAMAN-EDFA, RAMAN-SOA-EDFA and SOA-RAMAN-EDFA are evaluated and compared for 160 × 10Gbps DWDM system in the term of gain, received output power, Q Factor, eye height and minimum BER with nonlinearities at different transmission distance. The distance varied from 40 to 240 km in steps of 40 km. To analyze the system, the results of the first channel have been taken.

The Fig.2 shows the graphical representation of gain as a function of length in the presence of nonlinearities. The gain is decreased due to the fiber nonlinearities and fiber dispersion. The highest gain is provided by the SOA-RAMAN-EDFA amplifier for all over the distance range. At 40 km gain by SOA-RAMAN-EDFA amplifier is 53.06 dB and also for the 240 Km it becomes 50.84 dB. But for all other configurations power decreases linearly with the length of the fiber.

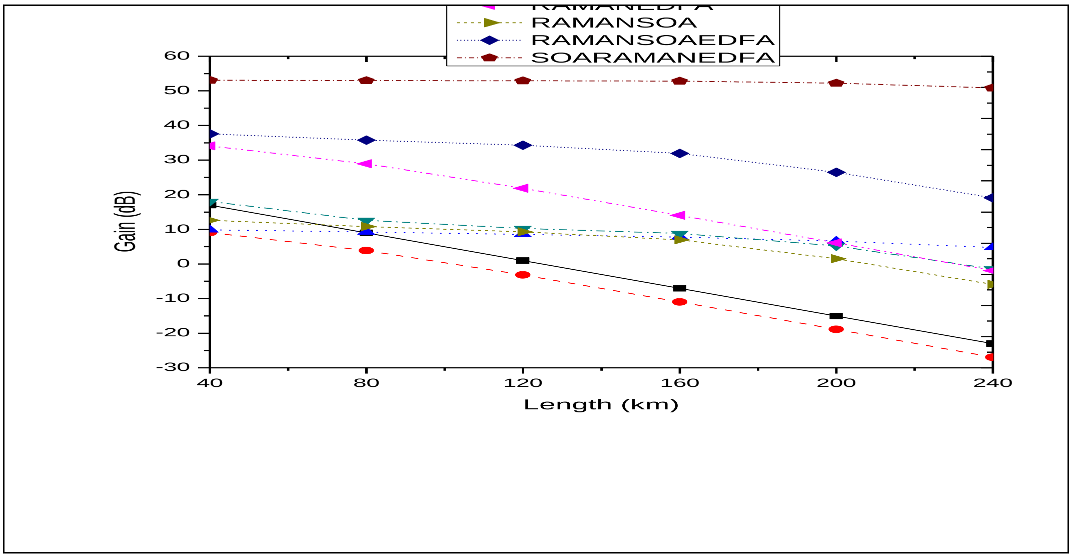

Fig. 2. Diagram Showing Gain at Different Fiber Length

The variation in gain is 16.99 to -23.03 dB for EDFA, 9.07 to -26.93 dB for RAMAN, 9.84 to 4.75 dB for SOA, 18.05 to -1.46 dB for EDFA-SOA, 34.08 to -1.91 dB for RAMAN-EDFA, 12.61 to -5.91 dB for RAMAN-SOA, 37.6 to 19.08 dB for RAMAN-SOA-EDFA, 53.06 to 50.84 dB for SOA-RAMAN-EDFA received by the proposed scheme.

The Fig.3 shows the graphical representation of output power as a function of length in the presence of nonlinearities. The output power is decreased due to the fiber nonlinearities and fiber attenuation. The better output power is provided by the SOA-RAMAN-EDFA amplifier for all over distance range. At 40 km output power by SOA-RAMAN-EDFA is 39.91 dBm and also for the 240 Km it becomes 37.7 dBm. But for other configurations power decreases linearly with length of the fiber.

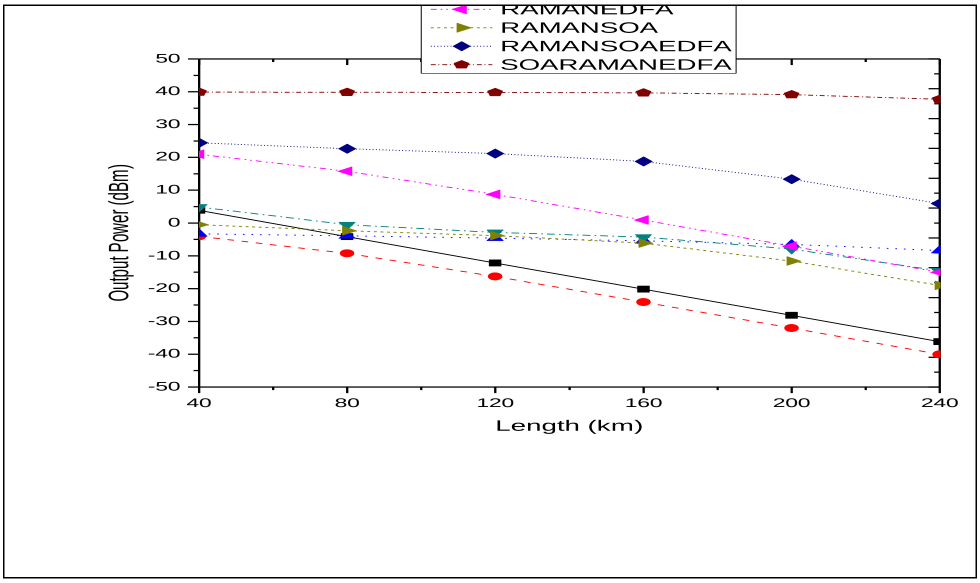

Fig. 3. Diagram Showing Output Power at Different Fiber Length

The variation in output power is 3.85 to -36.18 dBm for EDFA, -4.06 to -40.07 dBm for RAMAN, -3.29 to -8.38 dBm for SOA, 4.91 to -14.6 dBm for EDFA-SOA, 20.94 to -15.05 dBm for RAMAN-EDFA, -0.52 to -19.05 dBm for RAMAN-SOA, 24.46 to 5.93 dBm for RAMAN-SOA-EDFA, 39.91 to 37.7 dBm for SOA-RAMAN-EDFA received by the proposed scheme.

The Fig.4 shows the graphical representation of log of BER as a function of distance in the presence of nonlinearities. The better BER is provided by the SOA-RAMAN-EDFA amplifier for all over distance range. Other single and hybrid amplifiers also provides the acceptable BER but there is very much variation in BER.

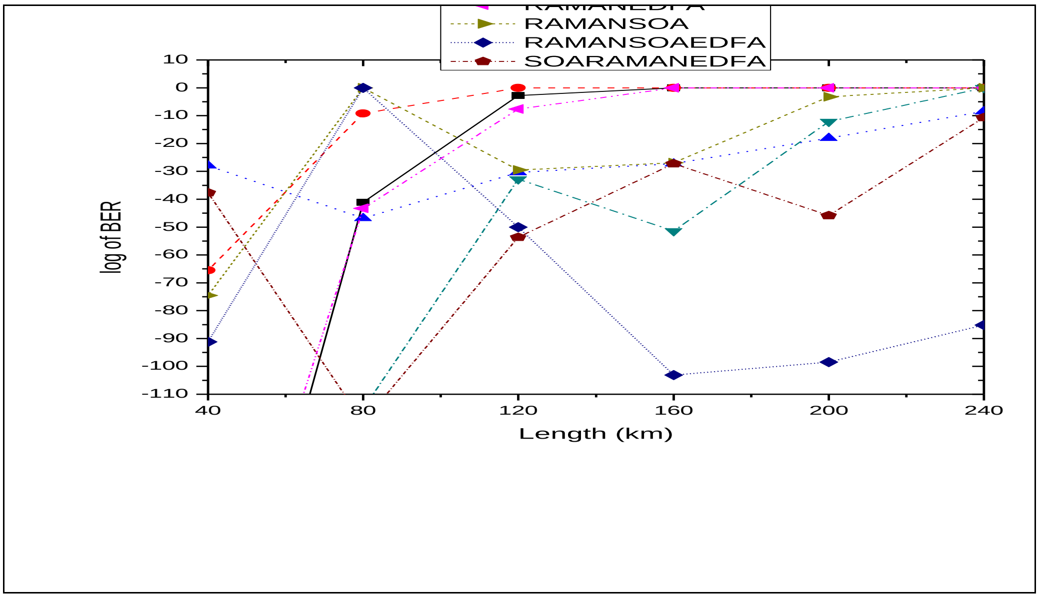

Fig. 4. Diagram Showing log of BER at Different Fiber Length

The variation in log of BER is -241.48 to 0 for EDFA, -65.51 to 0 for RAMAN, -27.96 to –8.49 for SOA, -195.18 to 0 for EDFA-SOA, -216.48 to 0 for RAMAN-EDFA, -74.54 to 0 for RAMAN-SOA, -91.16 to -85.17 for RAMAN-SOA-EDFA, -37.66 to -10.62 for SOA-RAMAN-EDFA.

The Fig.5 shows the graphical representation of Eye height as a function of distance in the presence of nonlinearities. The maximum eye height is provided by the SOA-RAMAN-EDFA amplifier for all over the distance range. It is observed that SOA-RAMAN-EDFA has maximum value of (14.32) at 80 km distance.

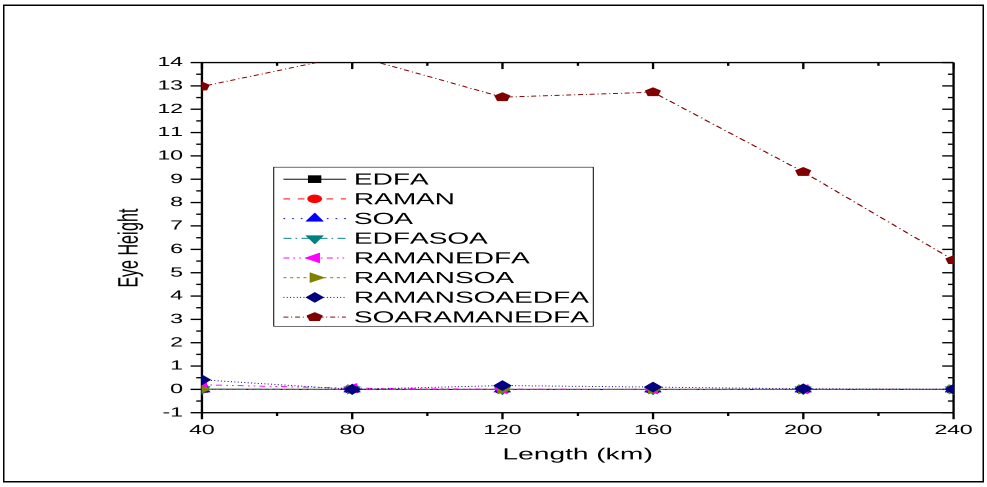

Fig. 5. Diagram Showing Eye Height at Different Fiber Length

The variation in eye height in a.u. is 3.87×10^{-3} to 0 for EDFA, 5.6×10^{-4} to 0 for RAMAN, 5.9×10^{-4} to 9.9×10^{-5} for SOA, 4.6×10^{-3} to 0 for EDFA-SOA, 1.9×10^{-1} to 0 for RAMAN-EDFA, 1.2×10^{-3} to 0 for RAMAN-SOA, 4.1×10^{-1} to 4.1×10^{-3} for RAMAN-SOA-EDFA, 12.98 to 5.54 for SOA-RAMAN-EDFA received by the proposed scheme.

The Fig.6 shows the graphical representation of Q-factor vs. Length for 160 channels in the presence of nonlinearities. The Q factor for SOA-RAMAN-EDFA amplifier received is highest as compare to other amplifier configurations for all over the range. It has maximum value 20.97 at 80 km distance.

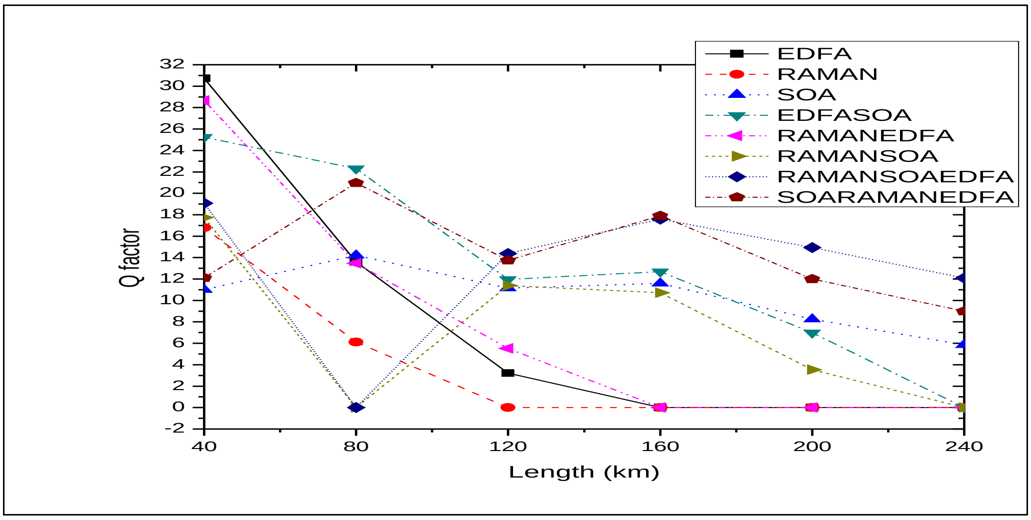

Fig. 6. Diagram Showing Q Factor at Different Fiber Length

The Q-factor for all the configurations is 30.74 to 0 for EDFA, 16.79 to 0 for RAMAN, 11 to 5.85 for SOA, 25.25 to 0 for EDFA-SOA, 28.66 to 0 for RAMAN-EDFA, 17.74 to 0 for RAMAN-SOA, 19.08 to 12.09 for RAMAN-SOA-EDFA and 12.12 to 9 for SOA-RAMAN-EDFA for 40 to 240 km range.

IV. Conclusion

The single and hybrid optical amplifiers for 160 × 10Gbps at 25 GHz frequency spacing design models were successfully designed and implemented into Optisystem.v7.0. The main motivation of this work is to increase the distance for long haul communication and large spectral bandwidth and flexibility of the optical networks. To achieve these goals, optical amplifiers have an important role in optical communication systems and networks. In long haul communication for repeater less transmission multiple optical amplifiers are used in system. So, for this hybrid optical amplifiers are used in the channel.

In this thesis the performance of single and hybrid optical amplifiers was evaluated using the gain, output power, BER, eye height and Q factor. The simulation results show that SOA-RAMAN-EDFA performed better than other optical amplifiers at all over the distance. By the proposed scheme SOA-RAMAN-EDFA provide highest gain (53.06 to 50.84 dB), high output power (39.91 to 37.7 dBm), least log of BER (-37.66 to -10.62), high eye height (12.98 to 5.54 a.u.) and large Q factor (12.12 to 9) for transmission distance ranging from 40 to 240 km. But it is useful up to 240 km above 240 km distance; there is more distortion in the received signal. The gain, output power, Q factor and eye height are decreasing above this. Also, there is an increment in BER after 240 km. So, this proposed model for SOA-RAMAN-EDFA is best suited for up to 240 km distance.

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