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New Simulation and Analysis Backward Pumped Fiber Raman Amplifiers Gain with Minimum Attenuation

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Abstract-

Raman Amplifiers (RAs) are a group of amplifiers which have various applications in optical communications. Data transmission media utilized for RAs are optical fibers operating in nonlinear regime. We present the performances and characteristics of RAs by utilizing a set of coupled differential equations and numerical simulations. The purpose of this paper is to simulate and analyze the parameters affecting on Raman gain for all optical backward pumped fiber Raman amplifier such as fiber type, fiber length, pump power and gain coefficient for enhancement the gain attenuation of fiber Raman amplifier. Three types of fibers with different gain characteristics are used in our numerical simulations. So, the optimum initial values of the pump powers for a system with three pumps are recalculated and optimized again.

Keywords: Raman Amplifiers, Distributed Raman Amplifier, Pump Power and Gain Coefficient

1. INTRODUCTION

The rapid revolution of communications in the last few years has opened the field of research on optical communication and placed it on research objectives in communications engineering, and also the broad features of optical networks make it as back bone communication systems. One solution to renew the signal is to convert the optical signal to the electric field and then convert it back to a new optical signal. However, pure optical amplifiers are usually preferred [1]. When the Raman pump wave has slight random power fluctuations in time, it is almost the case, individual bits, differential amplification, which can lead to capacitance fluctuations or jitter. If the rear pump is applied, the average voltages in amplitude [2] will be calculated. Raman fiber amplifiers are now used all Raman or hybrid FRAs/EDFAs at both long distances and very long wavelength wavelengths divided by multiplex optical communication systems [3]. Optical amplifiers are essential elements of any fiber optic communication system. Although modern optical fibers have losses below 0.2 dB / km, the repeated amplification of the signal sent to its original power becomes necessary at sufficiently long distances. One solution to renew the signal is to convert the optical signal into the electric field and then convert it back to a new optical signal. [4] However, it is recommended that the amplification on the optical field be considered as conversion time, noise resulting from the conversion process, cost and reliability. Therefore, the optical amplifiers have advanced rank. It can help design optical transmission system issues such as mid-distance visually amplify, and enhance bandwidth using Raman optical amplification (ROA) technology. ROA does not suffer from EDFA limitations in that it can be integrated with transmission fibers, and is pumped at any wavelength to provide wide gain bandwidth and gain flatness by using a combination of different wavelength pumping sources. Raman amplifier is based on Raman scattering motif phenomena (SIRS) is a nonlinear optical process in which the photon is absorbed and called the photon pump by the material while simultaneously emit a photon of different energy. The difference in photon energy is compensated by changing the vibrational state of the substance [5]. There are two Raman speakers: a separate Raman amplifier and a Raman amplifier (DRA) distributed. The distributed fiber optic type is used as an active medium. If the amplifier is included in the box at the end of the transmitter or receiver of the system, it will call a separate Raman amplifier [6]. One of the most commonly used in contemporary submarines and long-distance terrestrial networks is the distributed Raman Amplifier (DRA), where Raman amplification can occur in any fiber at any signal wavelength by proper selection of the pump wavelength. The Raman gain process is very fast [7]. This paper presented two optical amplifiers in cascaded form to enhancement the attenuation in the gain of the amplifier the first is forward pump amplifier and the second is backward pump amplifier, also we simulate and analyze the parameters affecting on Raman gain of fiber Raman amplifier for three different fiber types.

2. MODEL AND EQUATIONS ANALYSIS

The typical DRA diagram uses two Raman fiber amplifiers the first front pump and the second is feedback pump Raman amplifier in a sequential form to enhance the Raman gain of feedback Raman amplifier is shown in Fig. 1. When the pump power propagates in the direction of the signal, it is called co- or forward pumping scheme, and when the pump travels in the opposite direction, it is called counter or backward pumping. The pump sources marked as P_{S1} and P_{S2} are placed at both ends of the transmission span and their power are switched in the medium of the silica fiber using optical couplers [8].

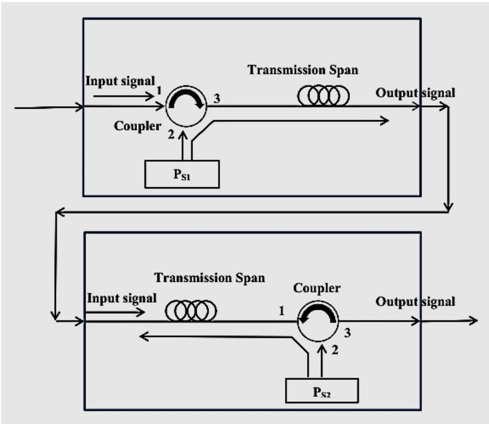

Fig. 1. Design model of Raman amplifier system scheme.

The fiber signal propagates in fiber media with the power signal according a couple of differential equation, this equation describe not only the signals attenuation due to propagation but also the power transfer from the power signal as follow [9-11]:

$$\pm\frac{\partial P_p}{\partial Z} = -\frac{\omega_p}{\omega_s} G_R P_p P_s - \alpha_p P_p \qquad (1)$$

$$\frac{\partial P_s}{\partial Z} = G_R P_p P_s - \alpha_s P_s \qquad (2)$$

Where G_R is the Raman gain coefficient related to the fiber type ($W^{-1}.m^{-1}$), α_s and α_p are the attenuation coefficient related to the optical signal and the pumping power in same order, ω_s and ω_p are the angular frequency related to the optical signal and the pumping power in same order [12].

Therefore to calculate the pump power at point z it can be used:

$$P_p(Z) = SP_p(0).e^{-\alpha_p Z(1-s)} = P_p(0).e^{-\alpha_p (L-Z)} \qquad (3)$$

If the values of P_P are substituted in differential equation (2), and it is integrated from 0 to L for the signal power in the forward and the backward pumping, it can be written as [13-15]:

$$P_s(Z) = P_s(0).e^{\left(G_R P_0\left(\frac{(1-\exp(-\alpha_p Z))}{\alpha_p}\right)-\alpha_s Z\right)} = G_F.P_s(0) \qquad (4)$$

$$P_s(Z) = P_s(0).e^{\left(G_R P_0\left(\frac{\exp(-\alpha_p L)(1-\exp(-\alpha_p Z))}{\alpha_p}\right)-\alpha_s Z\right)} = G_B.P_s(0) \qquad (5)$$

Where G_F, G_B are the net gain in the forward and backward pumping respectively. With P_O being the pump power at the input end, α_S and α_P are the linear attenuation coefficient of the signal and pump power in the optical fiber respectively, can be expressed as [16][17]:

$$\alpha_{S,P} = {}^{\alpha}/_{4.343} \qquad (6)$$

, Where α is the attenuation coefficient in dB/km.

From equation 4, 5 we can get the total gain of fiber Raman amplifier due to using forward pump Raman amplifier and feedback pump Raman amplifier in cascaded form to enhancement the Raman gain of feedback Raman amplifier can be expressed as:

$$G_T = G_F \times G_B \qquad (7)$$

Where, G_t the total gain of forward pump Raman amplifier and feedback pump Raman amplifier then,

$$G_T = exp\left[g_R P_0\, x\, \frac{\exp(-\alpha_P L)(\exp(\alpha_P\, z)-1)}{\alpha_P} - \alpha_S Z\right] \times exp\left[g_R P_0\, x\, \frac{1-\exp(-\alpha_P z)}{\alpha_P} - \alpha_S Z\right] \qquad (8)$$

$$G_T = exp\left[g_R P_0\, x\, \frac{\exp(-\alpha_P L)(\exp(\alpha_P\, z)-1)}{\alpha_P} + g_R P_0\, x\, \frac{1-\exp(-\alpha_P z)}{\alpha_P} - 2\alpha_S Z\right] \qquad (9)$$

$$G_T = exp\left[g_R P_0\, x\, \frac{a-b-c}{\alpha_P} - 2\alpha_S Z\right] \qquad (10)$$

Where;

$$a = exp(-\alpha_P L).\exp(\alpha_P\, z)\,, \quad b = exp(-\alpha_P L)$$

$$and\ \ c = exp(-\alpha_P Z)$$

The signal intensity at output of amplifier, fiber cable length L is determined by the following expression [18]:

$$P_s(L) = P_s(0)\exp\left(\frac{g_0\, P_0 L}{A_{eff}} - \alpha_s L\right) \qquad (11)$$

The effective length, L_{eff} is the length over which the nonlinearities still holds or stimulated Raman Scattering (SRS) occurs in the fiber and is defined as:

$$L_{eff} = \frac{1-\exp(-\alpha_p L)}{\alpha_p} \qquad (12)$$

Hence the amplification gain defined as the ratio of the power signal with and without Raman amplification, is given by the following expression [19]:

$$G_A = \frac{P_S}{P_S(0)\exp(-\alpha_s L)} \qquad (13)$$

3. RESULTS AND DISCUSSION

In this section the result simulated by using of two Raman fiber amplifiers the first forward pump Raman amplifier and the second is feedback pump Raman amplifier in cascaded form to enhancement the Raman gain of feedback Raman amplifier, where for backward Raman amplifier only the gain is attenuated from input signal power to intersect the zero axis or reach to zero and continues to negative part then reflect to increase to reach maximum value at fiber length spam, but in this case gain is start to increasing from zero to indicated value of Raman gain due to using forward pump Raman amplifier then the gain is attenuated slowly but doesn't reach to zero gain then occurs reflection to the gain to reach maximum value at final spam fiber length.

a. Relation between Raman Gain and Fiber Length at different pumping power

In this section we show, the variation of gain with fiber length for different pump powers 800, 1000 and 1200mW are given for a 100 km fiber length. As it is shown below for the three different fiber types (SMF, Freelight and Truewave) having different Raman gain coefficients and constant signal input power.

3.1.1 Relation between Raman Gain and Fiber Length at different pumping power for SMS Fiber Type

Figure 2; show the relation between Raman gain and fiber length for three different pump powers.

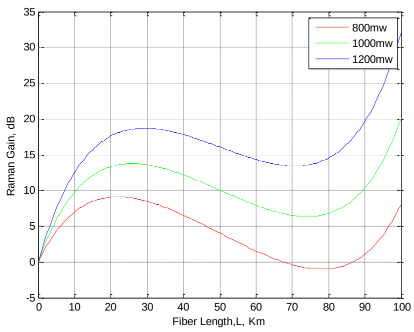

Fig. 2 Raman gain against the fiber length with different pumping power for SMF

This result simulated by using of two Raman fiber amplifiers the first forward pump Raman amplifier and the second is feedback pump Raman amplifier in cascaded form to enhancement the Raman gain of feedback Raman amplifier, where for backward Raman amplifier only the gain is attenuated from input signal power to intersect the zero axis or reach to zero and continues to negative part then reflect to increase to reach maximum value at fiber length spam as shown in previous results , but in this case gain is start to increasing from zero to indicated value of Raman gain as shown in figure 2 due to using forward pump Raman amplifier then the gain is attenuated slowly but doesn't reach to zero gain then occurs reflection to the gain to reach maximum value at final spam fiber length. This achieved by using high pumping power up to 800mW.

3.1.2 Relation between Raman gain and Fiber Length at different pumping power for Freelight Fiber Type

Figure 3; show the obtained gain from a model amplifier at different pump powers.

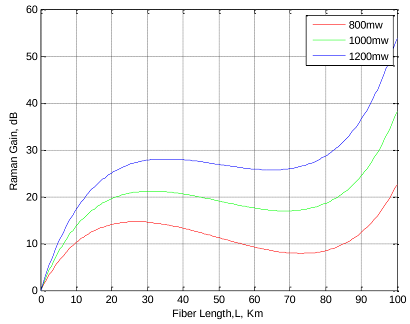

Fig. 3 Raman gain against the fiber length with different pumping power for Freelight

As shows figure 3, gain is start to increasing from zero to indicated value of Raman gain due to using forward pump Raman amplifier then the gain is attenuated slowly but doesn't reach to zero gain then occurs reflection to the gain to reach maximum value at final spam fiber length. This achieved by using high pumping power as shown in figure 3. Then we concluded that we must be increase the pumping power levels to reduced attenuation and increases the gain of the amplifier and in this case the gain doesn't reach to zero gain also this results give the freelight fiber type is the most powerful Raman amplification media than SMS fiber type this is because of large Raman gain coefficient and low power signal attenuation. Also, in case of 1000mW pumping power is better than in case of 800mW pumping power.

3.1.3 Relation between Raman gain and Fiber Length at different pumping power for Truewave Fiber Type

Figure 4; show the obtained gain from a model amplifier at different pump powers.

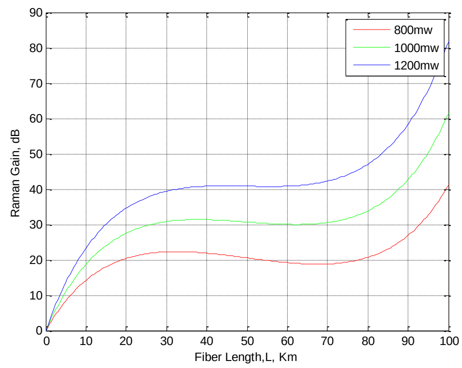

Fig. 4 Raman gain against the fiber length with different pumping power for Truewave

Also as shows figure 4, gain is start to increasing from zero to indicate value of Raman gain due to using forward pump Raman amplifier then the gain is saturated from 30km to 70km then gain is start to increasing to reach maximum value at final spam fiber length. This results give the truewave fiber type is the most powerful Raman amplification media than the other two types this is because of large Raman gain coefficient and low power signal attenuation. Also, in case of 1200mW pumping power is better than in case of 800 and 1000mW pumping power.

3.2 Relation between Raman Gain and Fiber Length for Different Fiber Types

In this section we show, the variation of gain with fiber length for the three different fiber types (SMF, Freelight and Truewave) having different Raman gain coefficients and constant signal input power and different constant pump powers (800mw, 1000mw and 1200mw)

3.2.1 Relation between Raman Gain and Fiber Length for Different Fiber Types at 800mw Pumping Power

Figure 5; show a comparison between three different fiber types (SMF, Freelight and Truewave) at 800mw pumping power for the fiber types having different Raman gain coefficients and constant signal input power.

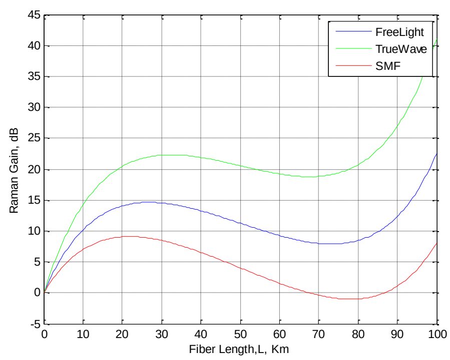

Fig. 5 Raman gain against the fiber length with different fiber types at 800mW pumping power

This result simulated by using of two amplifiers the first forward pump Raman amplifier and the second is feedback pump Raman amplifier in cascaded form to enhancement the Raman gain of feedback Raman amplifier, where for backward Raman amplifier only the gain is attenuated from input signal to intersect the zero axis or reach to zero and continues to negative part the reflect to increase to reach maximum value at fiber length spam as shown in previous results , but in this case gain is start to increasing from zero to indicated value of Raman gain as shown in figure 5 due to using forward pump Raman amplifier then the gain is attenuated slowly but doesn't reach to zero gain then occurs reflection to the gain to reach maximum value at final spam fiber length. This achieved by using high pumping power up to 800mW as shown in figure 5. This results give the truewave fiber type is the most powerful Raman amplification media than the other two types this is because of large Raman gain coefficient and low power signal attenuation.

3.2.2 Relation between Raman Gain and Fiber Length for Different Fiber Types at 1000mw Pumping Power

Figure 6; show a comparison between three different fiber types (SMF, Freelight and Truewave) at 1000mw pumping power for the fiber types having different Raman gain coefficients and constant signal input power.

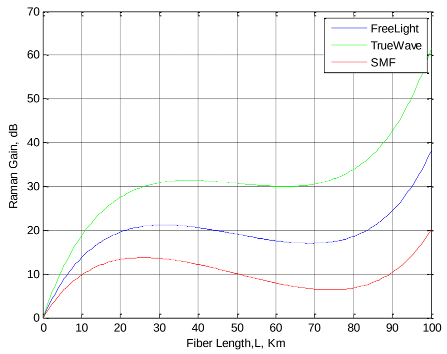

Fig. 6 Raman gain against the fiber length with different fiber types at 1000mW pumping power

Form figure 3, we get gain is start to increasing from zero to indicated value of Raman gain due to using forward pump Raman amplifier then the gain is attenuated slowly but doesn't reach to zero gain then occurs reflection to the gain to reach maximum value at final spam fiber length. This achieved by using high pumping power as shown in figure 3. Then we concluded that we must be increase the pumping power levels to reduced attenuation and increases the gain of the amplifier and in this case the gain doesn't reach to zero gain. This results give the true wave fiber type is the most powerful Raman amplification media than the other two types this is because of large Raman gain coefficient and low power signal attenuation.

Also, in case of 1000mW pumping power is better than in case of 800mW pumping power.

3.2.3 Relation between Raman Gain and Fiber Length for Different Fiber Types at 1200mw Pumping Power

Figure 7; show a comparison between three different fiber types (SMF, Freelight and Truewave) at 1200mw pumping power for the fiber types having different Raman gain coefficients and constant signal input power.

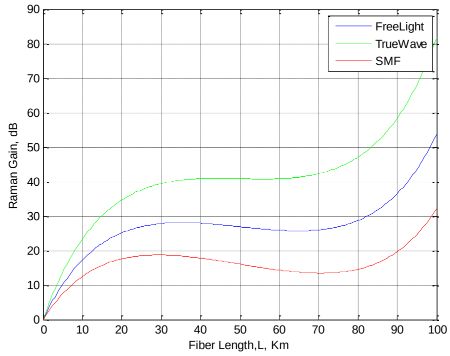

Fig7. Raman gain against the fiber length with different fiber types at 1200mW pumping power

As shows figure 7, gain is start to increasing from zero to indicate value of Raman gain due to using forward pump Raman amplifier then the gain is saturated from 30km to 70km then gain is start to increasing to reach maximum value at final spam fiber length. This results give the truewave fiber type is the most powerful Raman amplification media than the other two types this is because of large Raman gain coefficient and low power signal attenuation. Also, in case of 1200mW pumping power is better than in case of 1000mW pumping power and 800mW pumping power, then we get the attenuation in the gain is reduced by increasing the pump power but the gain is increases.

3.3 Output Signal Power Characteristics for Backward Pumping

This section show how the output signal power varies with the fiber length for different pump powers and fiber span of 100 km at a constant signal power, –3dBm, applied to the three fiber types.

3.3.1 Output Signal Power Characteristics for Backward Pumping at 800mW Pump Power

Figure 8; show the output signal power against fiber length at pump power 800mW and constant signal power, –3dBm, applied to the three fiber types.

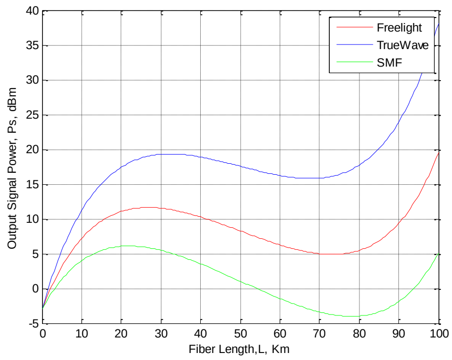

Fig. 8 Output signal power against fiber length at 800mW pumping power and -3dBm input signal power

Figure 8; was simulating the -3dBm of input signal along 100Km of fiber span and 400mW of pumping power in three different fiber types in case of SMS fiber type the output signal power is start to increasing from zero to indicated value of output signal power as shown in figure 8, due to using forward pump Raman amplifier then the output signal power is attenuated slowly to reach zero then occurs reflection to the output signal power at 80km fiber length to reach maximum value at final spam fiber length. But in case of Ferrlight the output signal power is start to increasing from zero to indicated value of output signal power as shown in figure 8, due to using forward pump Raman amplifier then the output signal power is attenuated slowly but doesn't reach to zero then occurs reflection to the output signal power to reach maximum value at final spam fiber length. and in case of Truewave fiber the output signal power is start to increasing from zero to indicated value of output signal power as shown in figure 8, due to using forward pump Raman amplifier then the output signal power is attenuated slowly then occurs reflection to the output signal power to reach maximum value at final spam fiber length. After simulation the output signal power for different fiber types along 100Km of fiber span and 800mW pumping power this results give the Truewave fiber type is the most powerful output signal power media than the other two types this is because of large Raman gain coefficient and low power signal attenuation.

3.3.2 Output Signal Power Characteristics for Backward Pumping at 1000mW Pump Power

Figure 9; show the output signal power against fiber length at pump power 1000mW and constant signal power, –3dBm, applied to the three fiber types.

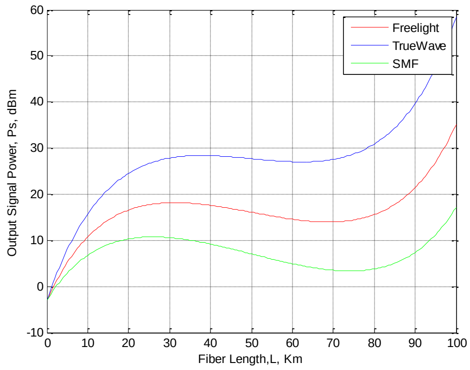

Fig. 9 Output signal power against fiber length at 1000mW pumping power and -3dBm input signal power

From figure 9, we get the output signal power is start to increasing from zero to indicated value of output signal power due to using forward pump Raman amplifier then the output signal power is attenuated slowly but doesn't reach to zero gain then occurs reflection to the output signal power at 70km fiber length to reach maximum value at final spam fiber length. But in case of Ferrlight output signal power is start to increasing from zero to indicated value of output signal power due to using forward pump Raman amplifier then the output signal power is attenuated slowly then occurs reflection to the output signal power at 70km fiber length to reach maximum value at final spam fiber length and in case of Truewave fiber the output signal power behave the same way of SMS and Freelight but output signal power is very high (is the best one).

After simulation the output signal power for different fiber types along 100Km of fiber span and 1000mW pumping power this results give the Truewave fiber type is the most powerful output signal power media than the other two types this is because of large Raman gain coefficient and low power signal attenuation.

3.3.3 Output Signal Power Characteristics for Backward Pumping at 1200mW Pump Power

Figure 10; show the output signal power against fiber length at pump power 1200mW and constant signal power, –3dBm, applied to the three fiber types.

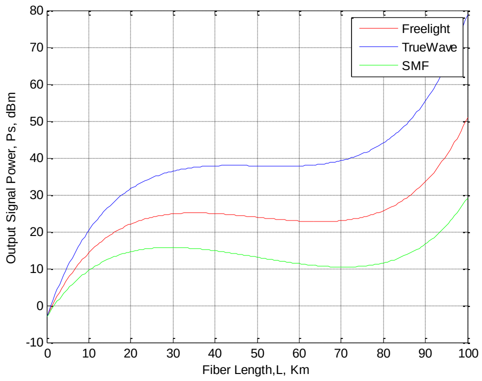

Fig. 10 Output signal power against fiber length at 1200mW pumping power and -3dBm input signal power

The result in figure 10, show output signal power is start to increasing from zero to indicate value of output signal power due to using forward pump Raman amplifier then the output signal power is saturated from 30km to 70km then output signal power is start to increasing to reach maximum value at final spam fiber length. This results give the truewave fiber type is the most powerful Raman amplification media than the other two types this is because of large Raman gain coefficient and low power signal attenuation. Also, in case of 1200mW pumping power is better than in case of 1000mW pumping power and 800mW pumping power, then we get the attenuation in the output signal power is reduced by increasing the pump power but the output signal power is increases.

4. CONCLUSION

Simulation results gives enhancement the gain of the amplifier, also we simulate and analyze the parameters affecting on Raman gain of fiber Raman amplifier for three different fiber types. The Raman gain of an optical signal is observed to depend on the selection of pump power. The FRA gain is obtained as a function of fiber length and pump power. According to the obtained results, gain is strongly dependent on the fiber length and pumping power. The differences between three different fiber types are satisfied.

REFERENCES

[1] Abd El–Naser A. Mohammed and Ahmed Nabih Zaki Rashed ", Comparison performance evolution of different transmission techniques with bi-directional distributed Raman gain amplification technique in high capacity optical networks", Journal of Electrical and Electronics Engineering Research Vol. 2(4), pp. 95-106, September, 2010.

[2] M.C. Fugihara, A.N. Pinto, "Low-Cost Raman Amplifier for CWDM Systems," Microwave and Optical Technology Letters, vol. 50, no. 2, pp. 297-301, Feb. 2008.

[3] Er. Jyoti Dhir and Er. Vivek Gupta," Improvement of Gain with Figure of Merit in Discrete Raman Amplifier", International Journal of Computer Science and Communication Engineering, (IJCSCE), pp. 22-24, 2013.

[4] A.N. Zaki Rashed, ", New trends of forward fiber Raman amplification for dense wavelength division multiplexing (DWDM) photonic communication networks", International Journal on "Technical and Physical Problems of Engineering,", vol. 3, no. 2, pp. 30-39, June 2011.

[5] Jyoti Dhir and Vivek Gupta, "Improvement of Raman Gain with Different Parameters in Discrete Raman Amplifier", International Journal of Engineering Research and Applications (IJERA), March 2014.

[6] Arwa H. Beshr, Moustafa H. Aly, and A.K. AboulSeoud2, "Amplified Spontaneous Emission Noise Power in Distributed Raman Amplifiers", International Journal of Scientific & Engineering Research, Volume 3, Issue 5, May-2012.

[7] Nihal M. Anwar, Moustafa H. Aly," Backward Pumped Distributed Fiber Raman Amplifiers", 27th National Radio Science Conference, March 2010.

[8] Ahmed H. Toeima, Moustafa H. Aly," Gain and Noise Performance of Fiber Raman Amplifiers", 5th International Computer Engineering Conference, December 2009.

[9] A. N. Zaki Rashed, "New Trends of Forward Fiber Raman Amplification for Dense Wavelength Division Multiplexing (DWDM) Photonic Communication

Networks", international journal of soft computing, vol. 6, no. 2, pp. 26-32, 2011.

[10] Felinsky and P.A. Korotkov, "Raman Threshold and Optical Gain Bandwidth in Silica Fibers," Journal of Semiconductor Physics, Quantum Electronics, and Optoelectronics, vol. 11, no. 4, pp. 360-363, July 2008.

[11] Jordanova LT. and Topchiev VI. "Improvement of the Optical Channel Noise Characteristics using Distributed Raman Amplifiers," ICEST, vol.12, no. 5, pp. 20-23, June 2008.

[12] Mohamed M. E. EL-Halawany, "Efficient Raman Amplifiers within Propagation and Multiplexing Techniques for High Capacity and Ultra Long Haul Transmission Systems," International Journal of Computer Science and Telecommunications, vol. 2, no. 3, pp. 16-24, June 2011.

[13] Er. Jyoti Dhir and Er. Vivek Gupta," Improvement of Gain with Figure of Merit in Discrete Raman Amplifier", International Journal of Computer Science and Communication Engineering, (IJCSCE), pp. 22-24, 2013.

[14] Parul Singh, "Analysis of Noise Figure of Fiber Raman Amplifier," International Journal of Science and Research (IJSR), vol. 3, pp. 997-999, 2014.

[15] Abd El–Naser A. Mohamed, Ahmed Nabih Zaki Rashed and Mahmoud M. A. Eid, "High Performance Efficiency of Distributed Optical Fiber Raman Amplifiers for Different Pumping Configurations in Different Fiber Cable Schemes", International Journal of Computer Science and Network (IJCSN), vol. 1, Issue 1, February 2012.

[16] S. Makoui, M. Savadi-Oskouei, A. Rostami, and Z. D. Koozehkanani, "Dispersion Flattened Optical Fiber Design for Large Bandwidth and High Speed Optical Communications Using Optimization Technique," Progress In Electromagnetics Research B, vol. 13, no. 3, pp. 21-40, 2009.

[17] M. El Mashade, M. B. and M. N. Abdel Aleem, "Analysis of Ultra Short Pulse Propagation in Nonlinear Optical Fiber," Progress In Electromagnetics Research B, vol. 12, no. 3, pp. 219-241, 2009.

[18] A. A. Mohammed and A. N. Zaki Rashed," Efficient distributed Raman gain amplification technique in modern metro passive optical networks", International Journal of Academic Library and Information Science, vol. 1, no. 1, pp. 10-23, August 2013.

[19] M. Wasfi, "Optical Fiber Amplifiers Review," International Journal of Communication Networks and Information Security (IJCNIS), vol. 1, no. 1, pp. 42-47, Apr. 2009.