



Analysis of Stimulated Raman Scattering Effect in WDM System

¹Harpreet Kaur, ²Gurpreet Singh, ³Jaskaran Kaur

¹M.Tech Scholar GNDU, ²Assistant Professor GNDU, ³M.Tech Scholar GNDU

Abstract—WDM systems have proved to be a good solution in increasing the capacity of an optical communication link by transmitting several wavelengths simultaneously through one fiber. But in WDM based fiber optic communication system, nonlinearities deteriorate network performance. Stimulated Raman Scattering (SRS) has a negligible impact on single channel systems but becomes important for WDM system because the power loss occur severely from lower wavelength to higher wavelength. The effect of Stimulated Raman Scattering (SRS) in WDM fiber optic system has been analysis by many authors with assumptions. There is further need to evaluate the effect of (SRS) accurately without any assumption. In this paper the analysis has been carried out for the estimation of (SRS).

Index Terms— Fiber nonlinearity, Fiber optic communication system, Stimulated Raman Scattering, Wavelength division multiplexing.

I. INTRODUCTION

Wavelength division multiplexing (WDM) allows information at various channels to be transmitted in different wavelength and hence fully exploits the vast bandwidth provided by optical fiber [1, 2]. It can both significantly enhance transmission capacity and provide more flexibility in optical network design. On one side the attempts are made to exploit the capabilities of fiber and to maintain high bit rate and long –haul transmission, on the other side undesirable fiber nonlinearities are likely to impose a transmission limit due to increased total interaction length.

There are number of optical nonlinear effects in optical fibers, such as Stimulated Raman Scattering effect (SRS), Stimulated Brillouin Scattering (SBS), Carrier Induced Phase Modulation and four wave mixing (FWM). Stimulated Raman Scattering (SRS) is among the significant nonlinear effect in single mode optical fibers. SRS degrades wavelength division multiplexed signal due to inter-channel crosstalk.

Some of the models [3,4] have taken into account the effect of pump depletion but still assume wavelength independent optical fiber loss/attenuation coefficient and hence wavelength independent effective length of fiber.

A numerical method of [5] evaluates SRS effect without any of the above mentioned assumptions and also takes into account the wavelength dependence of fiber loss coefficient. In short this numerical method evaluates the SRS effect without any assumption and give more accurate results.

II. EVALUATION OF SRS

As explained in [6] the power transfer from lower to higher wavelengths which are co-propagating in optical fibers leads to amplification of higher wavelength signals at the expense of the lower wavelength signals which are depleted of the useful signal power. The modified signal powers at various wavelengths can be evaluated using Eq.(1) [7].

$$P_M[k] = P_T[k] - P_T[k] \sum_{i=k+1}^N D[k, i] + P_T[k] \sum_{j=1}^{k-1} P_T[j] D[j, k]$$

for $k = 1, 2, \dots, N$

where $D[k, i] = 0$ for $i > N$ and $D[j, k] = 0$ for $k = 1$ (1)

In Eq.(1) 2nd the term gives the total power depleted from the k^{th} channel by the higher wavelength channels and 3rd term indicates the total power depleted by the k^{th} channel from the lower wavelength channels. While evaluating the above equations, simultaneous power transfer among different wavelength channels is assumed. $P_T[i]$ and $P_M[i]$ are the optical power launched in the i^{th} channel and the modified power in the i^{th} channel due to SRS effect after propagation over a given length of optical fiber, respectively.

$D[i, j]$ represents the fraction of power depleted from the i^{th} channel by the j^{th} channel for $j > i$, i.e., the j^{th} channel is at a wavelength longer than that of the i^{th} channel [7].

$$D[i, j] = \left(\frac{\lambda_j}{\lambda_i}\right) P_T[j] \left\{ (f_i - f_j) / 1.5 \times 10^{13} \right\} g_{Rmax} \times \{(L_e(\lambda_j) \times 10^5) / (b \cdot A_e)\}$$

$$D[i, j] = 0 \text{ for } (f_i - f_j) / 1.5 \times 10^{13} \text{ Hz and } j \leq i \quad (2)$$

g_{Rmax} is peak Raman gain coefficient. λ_i, λ_j are the wavelengths (nm) of i_{th} and j_{th} channels and f_i, f_j are the center frequencies (Hz) of the i_{th} and j_{th} channels. A_e is effective core area of optical fiber in cm^2 . $P_T[j]$ is optical power in 1 mw watts launched in the j_{th} channel and value of b varies from 1 to 2 depending upon the polarization state of the signals at different wavelength channels, $b=2$ is considered for scrambled polarization.

Amplification will decrease in a long fiber because of pump absorption due to fiber loss. This is handled by calculating effective length. L is actual fiber length in km and $L_e(\lambda_j)$ is wavelength dependent effective length in km which is calculated using Eq.(3) given below. The effective length is calculated taking different value of length in (Km). Then see the variation of effective length of optical fiber with wavelength [7].

$$L_e(\lambda_j) = \left\{ 1 - \exp \left[\frac{-\alpha(\lambda_j)L}{4.343} \right] \right\} \left[\frac{4.343}{\alpha(\lambda_j)} \right] \quad (3)$$

where $\alpha(\lambda_j)$ is wavelength dependent linear loss coefficient of optical fiber in (dB/km). For calculating $\alpha(\lambda_j)$ Eq. (4) is developed by taking in to account the variation in linear loss coefficient with wavelength up to 0.7dB, over 25 nm bandwidth (in 1.55 nm transmission window) and 100 km fiber length (confirmed by the experimental results [9]).

$$\alpha(\lambda_j) = \{ \alpha_{max} - [(\lambda_j - \lambda_1) / \Delta WDM] (\alpha_{max} - \alpha_{min}) \}$$

$$\alpha_{max} = \alpha + \alpha_{var} / 2$$

$$\alpha_{min} = \alpha - \alpha_{var} / 2$$

$$\alpha_{var} = (0.0075 / 25) \cdot \Delta WDM \quad (4)$$

Where ΔWDM is spectral width of WDM signal (i.e., separation between the shortest wavelength channel and the longest wavelength channel) in nm, and λ_j and λ_1 are wavelengths of channel # j and channel #1, respectively, in (nm) and α_{var} is in (dB/km) and α is fiber loss coefficient (dB/km) at center wavelength. It is assumed that α varies linearly with wavelength. However, in transmission window other than 1.55 (μm) window, the variation of fiber loss coefficient with wavelength will differ and so the factor 0.007/25 in Eq. (4) will have to be changed accordingly. This makes capable of taking in to account the effect of wavelength dependent linear loss coefficient of fiber while calculating SRS induced spectral distortion in WDM fiber optic systems [7].

III. METHODOLOGY

In the present work, the evaluation of SRS effect has been done with the help of programming in the MATLAB as per the mathematical relation given in the section 2.

Values of important parameter chosen for calculation are given in table [8].

S. no	Parameter Name	Value
1	Peak Raman Gain Coefficient	10.05×10^{-12} cm/W
2	Input Power Per Channel	1 Mw
3	Fiber Attenuation Coefficient	0.205 dB/km
4	Area of optical fiber	5.3×10^{-7} cm ²
5	Length of optical fiber	10,50,500 km
6	Inter Channel Separation	0.8 Nm

IV. RESULTS AND DISCUSSIONS

First of all variation of linear loss coefficient vs. wavelength of channel has been shown in Figure 2,3,4 which has been plotted with the help of MATLAB programming using Eq. 4. These has been plotted for channel 2,4,8 using inter-channel separation 0.8. It can be seen from the plots that the value of linear loss coefficient decreased as the wavelength of channel increased. Linear loss has been represented in (db/km) and wavelength in (nm).

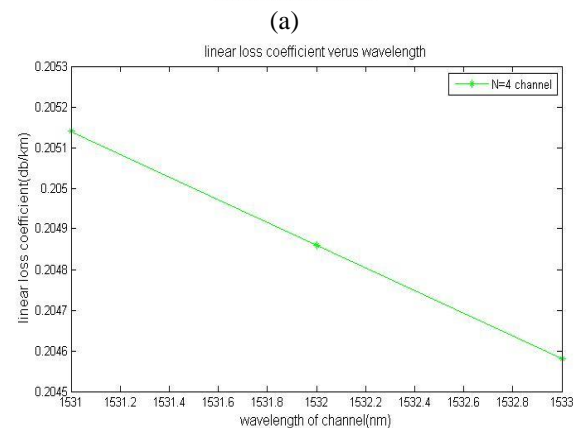
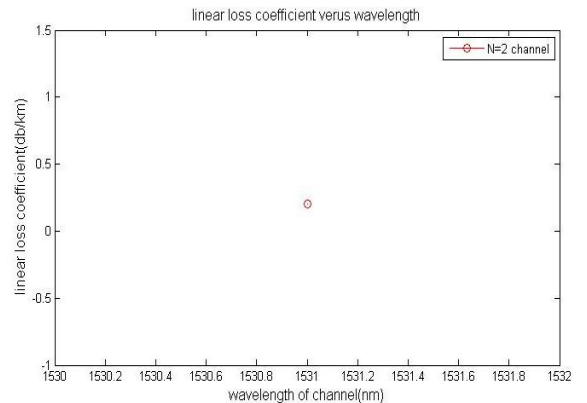


Fig 1 (a),(b) Linear loss coefficient as function of wavelength of channel for different number of channels

The variation of effective length vs. wavelength of channel has been reported in Figure 2 which has been plotted for channel 2,4,8, fiber length 10,50,500 Km and

inter channel separation 0.8 Km. It has been observed from the plots that the effective length increased as the wavelength of channel and the length of fiber increased.

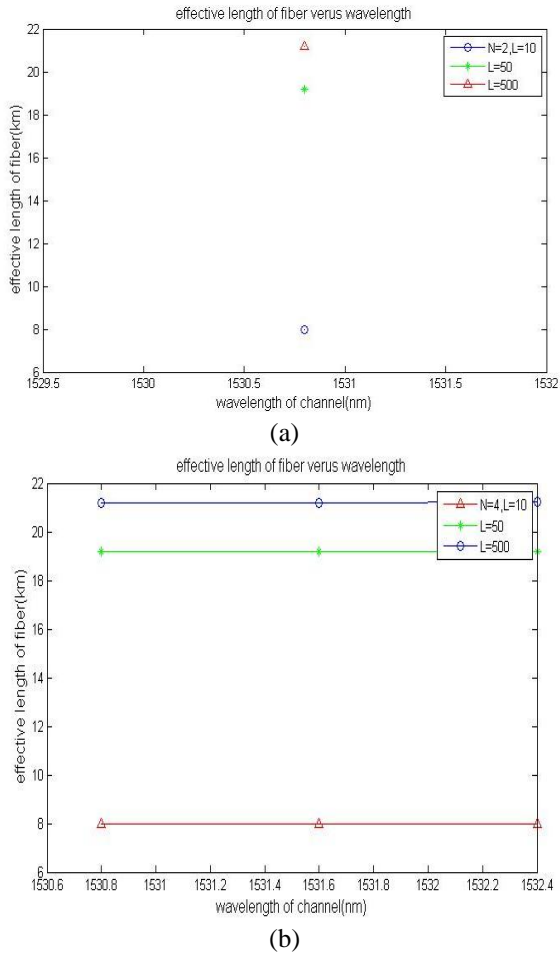


Fig 2 (a),(b) effective length as function of wavelength of channel for different number of channel

The modified signal power due to SRS effect (dbm) vs. wavelength of channel has been shown in Figure 3 which has been plotted for channel 2,4,8, for fiber length 10 km, inter channel separation 0.8 km. It can be inferred from these plot that the signal power of higher wavelength channels has grown at the expense of lower wavelength channels. It has been seen that signal power linear increased with the increased in the wavelength of the channel.

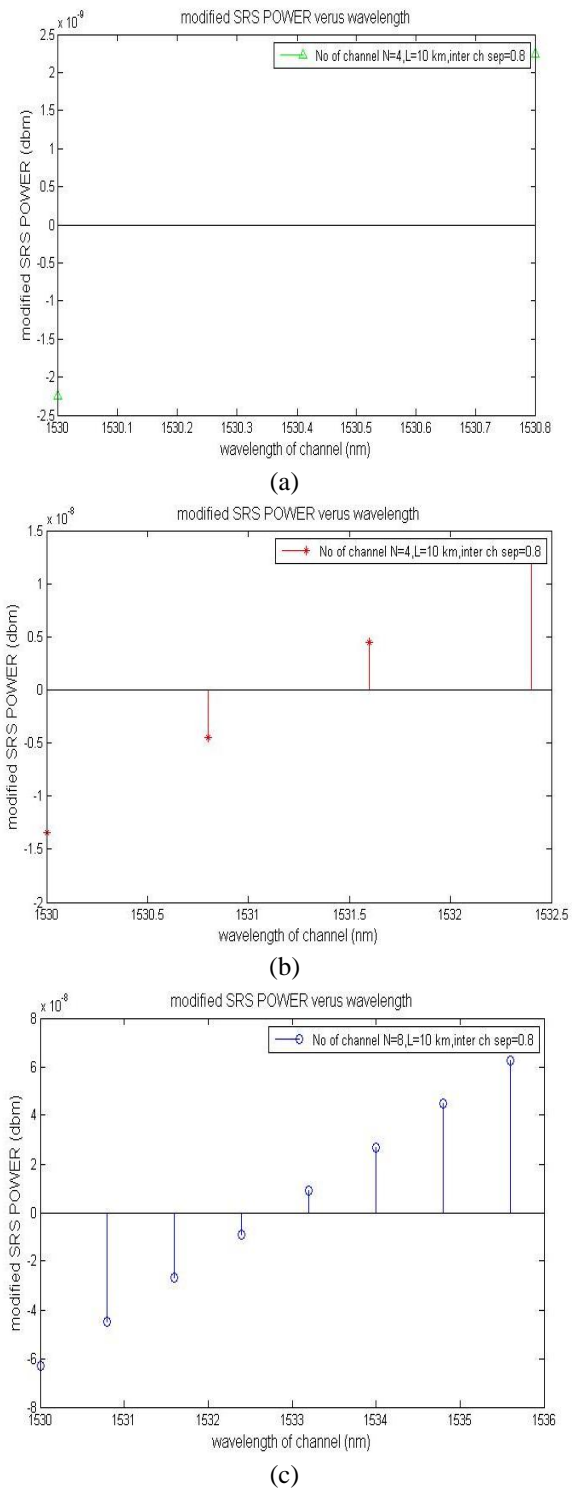
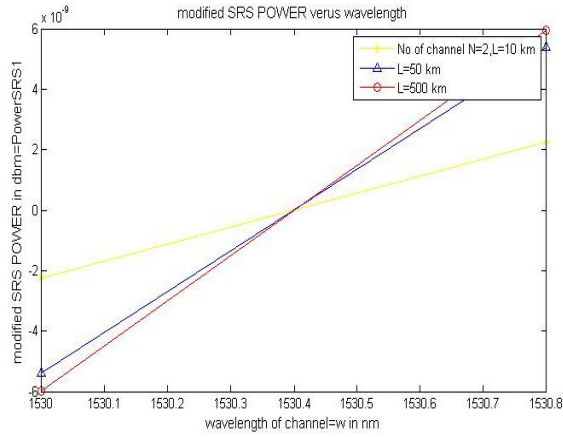
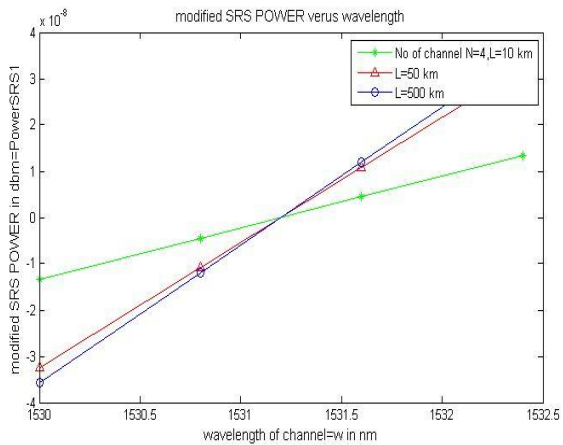


Fig 3 (a),(b),(c) modified SRS power as function of wavelength of channel for different number of channels

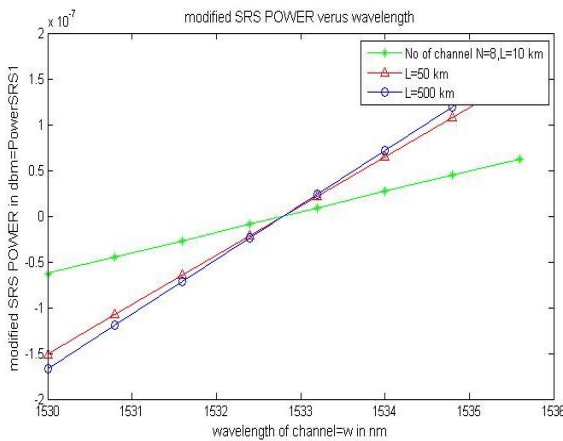


(a)



(b)

The variation of the modified power vs. wavelength at different length for different number of channel like 2,4,8 at different value of length like 10,50,500 km has been illustrated in figure 4(a),(b),(c) with the help of MATLAB program. It can be seen from these plots that the modified power has been increased as the wavelength and the length of fiber increased because the power transfer from lower wavelength channel to higher wavelength channels. So the lowest wavelength channel experience worst degradation and highest wavelength channel no degradation. The SRS effect increases with wavelength at different value of length.



(c)

Fig 4 (a),(b),(c) modified SRS power as function of wavelength of channel at different value of length for different number of channels

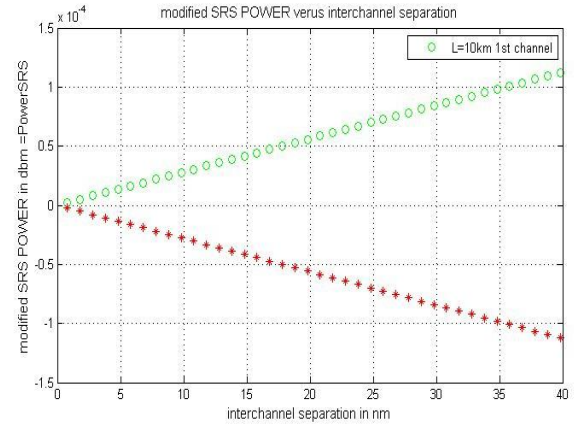


Fig 5 Modified SRS power as function of inter channel separation for number of channel 2

Fig 5 has been described the behavior of modified SRS power with inter channel separation for number of channel 2. The trend that as the value of inter channel separation increased the power of 1st channel decreased and power of 2nd channel increased. The SRS effect enhance with inter channel separation or channel spacing.

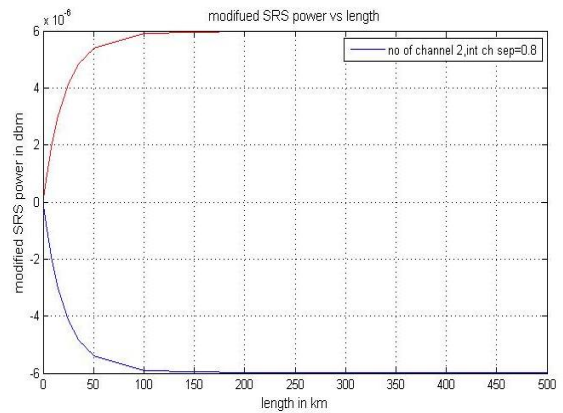


Fig 6 Modified SRS power as function of length for number of channel 2

From the above plot has been observed that as the value of length increased the power of 1st channel decreased and power of 2nd channel increased. This may be attributed to fact that with increase in the system length, the number of segment increases, which turn increase the SRS effect.

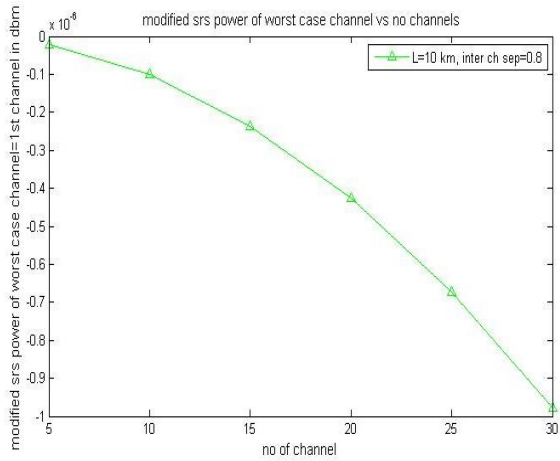


Fig 7 Modified SRS power of worst case channel as function of number of channels.

The worst case channel is lowest wavelength channel (1st channel) in WDM system, that losses the most in term of power depletion. From the plot has been observed that the modified power of worst case channel decrease as the number of channel increase, because the power transfer from lower wavelength channel to higher wavelength channel. So 1st channel experience the worst degradation.

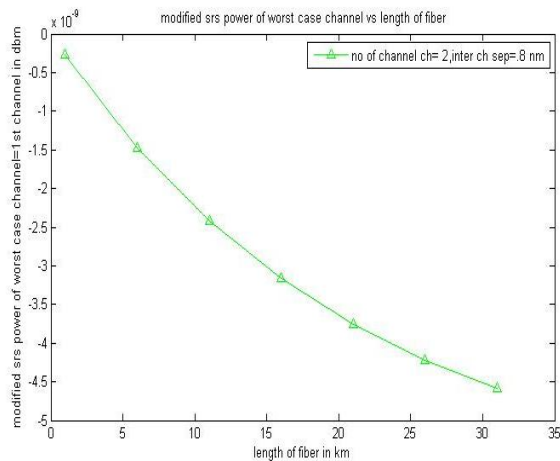


Fig 8 Modified SRS power of worst case channel as function of length of fiber

The fig 8 has been described that as the length of fiber increases the modified power of channel decreases. This may be attributed to fact that with increase in the system length, the number of segment increases, which turn increase the SRS effect.

The given below figure 9 has been depicted that the variation of modified power of worst case channel with the inter channel separation. It has been cleared from the figure that the modified power of 1st channel is decreases as the inter channel separation increases, because the power transfer from lower wavelength channel to higher wavelength channel.

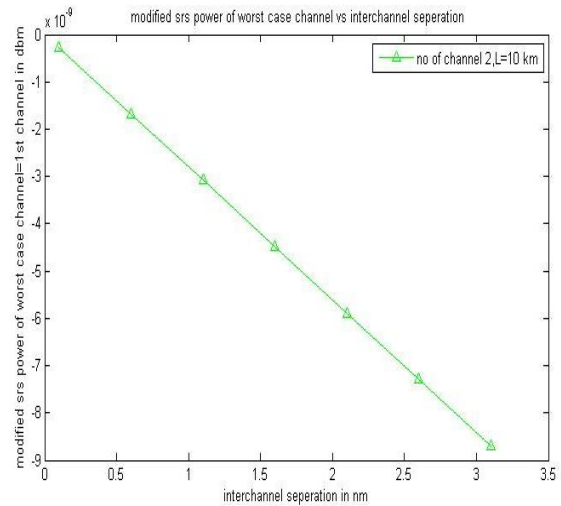


Fig 9 Modified SRS power of worst case channel as function of inter channel separation

V. CONCLUSION

In this paper work the analysis has been carried out for estimation of SRS effect with the help of MATLAB programming. It has been concluded from the analysis that the Linear loss parameter decrease and effective length of fiber increase as the wavelength of channel or channel number increase. The modified SRS power increase as wavelength increase and value of length increase because the power transfer from lower wavelength channel to higher wavelength channel which are co propagating in optical fiber leads to amplification of higher wavelength signal at the expense of lower wavelength signal which are depleted of useful signal power.

The behavior of SRS modified power has been seen with inter channel separation and the length of fiber for number of channel 2. Here also same trend has been observed that modified power of higher wavelength channel increase and lowest wavelength decrease as the length of fiber and inter channel separation increase.

At the end has been depicted that the behavior of worst case channel with number of channels, length of fiber, inter channel separation. When the value of these parameter increase the modified SRS power of worst case or 1st case channel decrease.

All these parameter like number of channel and length of fiber, inter channel separation enhance the SRS effect . These parameter increase the SRS effect in sequence number of channel > inter channel separation > length of fiber. Most effected parameter is number of channel and the least effected parameter is length of fiber for SRS effect

VI. FUTURE SCOPE

To modified the program to optimize other varying parameter such as inter amplifier separation, input power etc. Also evaluate the SRS effect with different data rate. Find the way how to reduced the tilt in signal power due to SRS effect because SRS effect became limiting factor for lower wavelength channel. Also compare the effect of input power, number of channels, length of fiber, inter channel separation, wavelength on modified SRS power and without SRS effect power.

REFERENCES

- [1] C.A Brackett, "Dense Wavelength Division Multiplexing Networks Principles and Application," IEEE J Select. Areas Commun., vol. 8, pp. 948-964, 1990.
- [2] P. E. Green, "The future of Fiber-Optic Computer Networks ," IEEE Computer, vol. 24, pp. 78-87,1991.
- [3] D.N. Christodoulides, R.B. Jander, Evolution of stimulated Raman cross talk in wavelength division multiplexed systems, IEEE Photonic. Technol. Lett. 8
- [4] M. Zirngibl, Analytical model of Raman gain effects in massive wavelength division multiplexed transmission systems, Electron. Lett. 34 (8) (1998) 789–790.
- [5] M.L. Singh, I.S. Hudiara, A piece wise linear solution for nonlinear SRS effect in DWDM fiber optic communication systems, SBMO J. Microwaves Optoelectron. 3 (4) (2004) 29–38.
- [6] Gurmeet Kaur,M.S.Patterh, "Impact of pulse walk off effect on Stimulated Raman Scattering in a DWDM transmission system",2009.
- [7] Maninder Lal Singh, "Effect of pulse walk off and data formats on stimulated Raman Scattering in fiber optic communication systems",2008.
- [8] Dr. M.L. Singh, Prof. I.S Hudiara and Vibhu Sharma "EVALUATION OF SRS INDUCED SPECTRAL DISTORTION IN WDM FIBER OPTIC SYSTEM AND ITS MINIMISATION USING SPECTRAL INVERSION METHOD".
- [9] S. Bigo, S. Gauchard, A. Bertaina, J.-P. Hamaide, Experimental investigation of stimulated Raman scattering limitation on WDM transmission over various types of fiber infrastructures, IEEE Photonic. Technol Lett. 11 (6) (1999) 671–673.

