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Pulse Walk off Effect on Stimulated Raman Scattering

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Abstract—*This article presentsalmost constant modulated stimulated Raman Scattering power using pulse walk off effect by linear power division approximation algorithm. Due to SRS effect power distributed for shorter wavelength pulse is small and for higher wavelength power is high. Power tilt Because of SRS effect has been calculated at optical Manchester. Power has been varied from 1 to 60 mW. Using pulse walk off rule effect on channel was done. Pulse walk off rule limit the effective length and number of channels increases. Using this algorithm, efficiency is also increased.*

Keyword*: Nonlinearity, dense wavelength-division multiplexing, linear power approximation,transmitted power, Stimulated Raman Scattering, number of channels, modulated power, pulse walk off, optical Manchester.*

1. INTRODUCTION

Non-linear effect arises due to change in refractive index with optical intensity & scattering phenomenon.Refractive index is depend on power is responsible for Kerr effect. At high power level inelastic phenomenon induce stimulated effect such as stimulated Raman Scattering(SRS) and Stimulated Brillouin Scattering(SBS). If the incident power exceed certain threshold intensity of light grows exponentially. Difference between Brillouin and Raman scattering is that SRS generated optical phonon are incoherent while SBS generated acoustic phonon are coherent.SRS threshold is close to 1w which is 100 times higher than SBS threshold.Scattered light shifted in frequency is13thz in SRS while in SBS is 10 GHz.SRS is much of less problem than SBS.With erbium-doped fiber amplifier(EDFA) output power is 500 mw and will go higher. Three optical amplifier reach this limit and limit drop proportionally by using number of optical amplifier in series[1-5].

Effect of SRS studies in DWDM taking an assumption like triangular approximation of Raman gain spectrum,when short wavelength transformed into a long wavelength photon no energy loss occur. Model [6-7] evaluate effect of SRS using wavelength independent optical fiber loss and hence wavelength independence, effective length of fiber,While model [8] assume wavelength dependence of the fiber loss coefficient. In this paper the model evaluates the SRS effect by using pulse walk off rule and data format. This gives move accurate results.

2. MATHEMATICAL MODEL

As explained in [8] the power transfer among the different wavelength channel i.e. from lower to higher wavelength. The graphical representation of depletion and amplification of optical power at different wavelength channel due to SRS.

The modified signal power at various wavelength can be obtained by using equation (1)

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

For k=1, 2,……N. (1)

Where D[k,i]=0 For $i > N$ and D[j,k]=0 for k=1

In eq.(1) the term $P_T[k]\sum_{i=k+1}^{N} D[k,i]$Power depleted from k^{th} channel by the higher wavelength channel and $\sum_{j=1}^{k-1} P_T[j]D[j,k]$Indicatepower depleted from k^{th} channel by lower wavelength channel.$P_T[k]$And $P_M[k]$ are an optical power launched in k^{th} channel and modified power in the k^{th} channel propagation over a given length of fiber.

Actual received power $P_T[k]$ in the k^{th} channel following received equation as:

$$P_T[k] = P_M[k] \times \exp\{-a(\lambda_k)\times L\} \quad (2)$$

D[i,j] represent the power depleted from i^{th} channel by j^{th} channel

$$D[i,j] = \left(\frac{\lambda_j}{\lambda_i}\right) P_T[j]\{(f_i - f_j)/1.5\times 10^{13}\} g_{R\,max} \times \{(L_e(\lambda_j)\times 10^5)/(b.A_e)\} \text{for} \quad (f_i - f_j) \le 1.5\times 10^{13}\text{Hz and } j > i$$

D[i,j]=0 for $(f_i - f_j) > 1.5\times 10^{13}$Hz and $j \le i$ (3)

$g_{R\,max}$ Is peak gain coefficient (cm/W).λ_i, λ_j Are the wavelength of the i^{th} andj^{th} channel and f_i, f_j Are central frequency in Hz.A_e Is an effective area core area of optical fiber in cm^2.b varies from 1 to 2depending upon different wavelength channel polarization [9].L Length of fiber in km and$L_e(\lambda_j)$ is effective length in km expressed by equation (4) as:

$$L_e(\lambda_j) = \left\{1 - \exp\left[-\frac{\alpha(\lambda_j)L}{4.343}\right]\right\}[4.343/\alpha(\lambda_j)] \quad (4)$$

Where $\alpha(\lambda_j)$ is wavelength dependent linear loss coefficient of optical fiber in dB/km and it vary when wavelength upto 0.7 dB,over 25 nm bandwidth and 100 km fiber length[9]:

$$\alpha(\lambda_j) = \{\alpha_{max} - \lfloor(\lambda_j - \lambda_1)/\Delta_{wdm}\rfloor(\alpha_{max} - \alpha_{min})\}$$

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

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

$$\alpha_{var} = \left(\frac{0.007}{25}\right).\Delta_{wdm} \quad (5)$$

Δ_{wdm} is spectral width of DWDM is separation between highest and shortest wavelength channel λ_j and λ_1 in nm and α is fiber loss coefficient in dB/km.

3. PULSE WALK OFF AND DATA FORMAT

Power transfer occur among the co-propagating wavelength channel only when the pulses on both channels overlap. SRS effect will not result power transfer when pulse walk off completed. When the pulse at co-propagating wavelength align or walk in power transfer will restart.Pulsewalkoff limit the effective length. The change in effective length will be a function of thedispersion coefficient of the fiber, data rate, inter-channel separation and data format. Walk off length calculated using equation(6):

$$L_{walkoff} = \frac{10^3}{B \times D \times (\lambda_i - \lambda_j) \times 10^9} \quad (6)$$

Where B is the data rate in Gb/s,D is the dispersion coefficientof the fiber in ps/nm km,$(\lambda_i - \lambda_j)$ is the separation between the i^{th}andj^{th} channel nm.$L_{walkoff}$ is calculated in km.

Optical Manchester code

Manchester has transition at middle of each period and have transition at start of period. The direction of mid bit transition indicate data. Transition period boundaries do not carry information. This format is same as NRZ(non-return to zero)format except for the time shift of half bit periods. The occurrence of 1's and 0's the width of the pulse representing 1's in Manchester format is half the width of the pulse representing 1's in NRZ.This factor of 2 is used in the numinator while evaluating $L_{walk\ off}$ as given below:

$$L_{walkoff} = \frac{10^3}{2 \times B \times D \times (\lambda_i - \lambda_j) \times 10^3} \quad (9)$$

Case

1. Effective length $L_e$is less than or equal to $L_{Walkoff}$

No change in the L_e because of pulse walk off i.e $L_e = L_{Walkoff}$

2.$L_e > L_{Walkoff}$

Sub-case A. if

$$\frac{L_e}{L_{Walkoff}} = A + R$$

Where r is remainder, A is odd integer other than 1

$$L_e = \left(\frac{A+1}{2}\right)L_{Walkoff} + R$$

For A=1,$L_{e_{new}} = L_{Walkoff}$

Sub-case B. if

$$\frac{L_e}{L_{Walkoff}} = B + R$$

Where B is any even integer

$$L_{e_{new}} = \left(\frac{B}{2}\right)L_{Walkoff} + R$$

4. SIMULATION RESULTS

To transmit power linearly across channels, the transmitted power can be set according to equation(10),which provide approximate constant power across all channels according to the specified power value:

Corrected modulated=[slope*wavelength+{power+(slope*wavelength of third channel)}] (10)

Fig. 1 shows transmitted power for all twelve wavelengths have identical amplitude.it can be seen in modulated power that shorter wavelength has much smaller amplitude than longer wavelength is due to SRS effect. The linearly varying modulated channel can be decreased by using power specified by eq.(9).

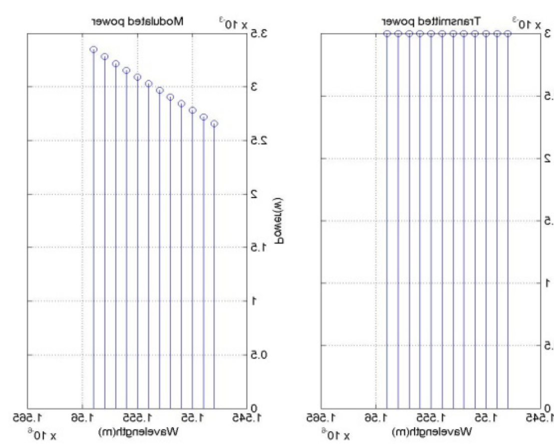

Fig. 1: Transmitted power and modulated power due to SRS effect including walk off effect.

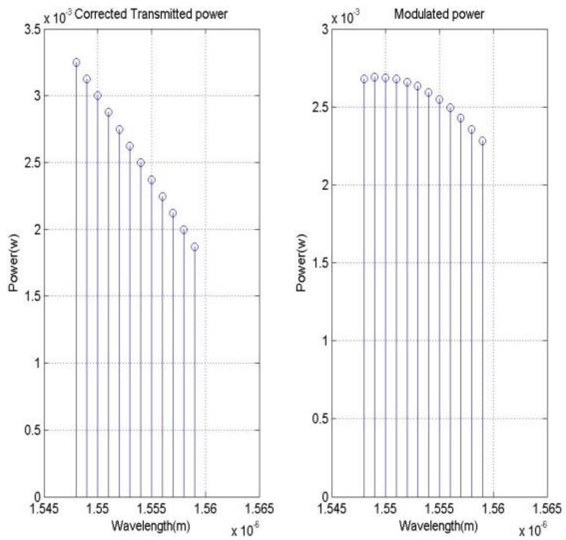

Fig. 2: Corrected or modulated power for ten channels.

Fig. 2 shows that modulated power for twelve channels nearly constant as if there is no effect of SRS in the channel.table 1 shows maximum no.of channel that can be corrected for a given power value using the proposed algorithm.

Table 1: Number of channel used for Optical Manchester

Power(mw)	Channel length (km)	Amplifier distance (km)	Number of channel wavelength
1 mw	2,000	100	22
2 mw	2,000	100	16
5 mw	2,000	100	10
10 mw	2,000	100	8
20 mw	2,000	100	6
25 mw	2,000	100	5

5. CONCLUSION

Fig. 2 and table 1 show that the use of linear approximation results in almost constant modulated power on given no. Of channel wavelength and given power; e.g.,for 1mw of power,a 30 channel DWDM system can be used. This algorithm reduces the effect of SRS by efficient power division. It can thus be said that using pulse walk off rule and optical Manchester format SRS effect reduces and almost constant modulated power is achieved across all wavelengths. It can also be said that using pulse walk off rule number of channel is increased and efficiency is also increased.

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