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Stimulated Raman Scattering Analysis of Wavelength Division Multiplexing (WDM) Channels in Optical Fiber

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Abstract: This paper analyses the performance of the systems affected by the cross talk induced Stimulated Raman Scattering (SRS). SRS has very little impact on system performance for a single channel system, however, it is one of the major non-linear effects in the dense wavelength division multiplexed (DWDM) fiber optics communication systems. The effect of SRS causes power to be transferred from lower wavelength channels to higher wavelength channels. This unwanted Power tilt reduces the optical signal to noise ratio (OSNR) which in turn increases the Bit Error Rate (BER). SRS effect could be reduced by setting optimum power in the fiber. The analysis of SRS was performed by setting various power levels and channel spacing of individual channels in DWDM system in the sample mode of OptSim software to get the effects of SRS like power tilt in the optical spectrum. Power tilt was observed for different cases like unequal channel spacing, equal channel spacing and different input power are provided to the system. It was found that unequal channel spacing between channels reduced the unwanted power tilt value. When the Input power was decreased, there was reduction in the unwanted tilt in optical power. However by reducing the input power, number of channels in a DWDM system decreased. Hence Optimum power level settings in the fiber have to be set for DWDM. Therefore, to reduce the power tilt value, minimum Input power and unequal channel spacing is to be given for the individual channels.

Keywords: WDM, SRS, OptSim, OSNR, BER.

I. INTRODUCTION

Optical signals are largely affected when light waves transmitted through optical fiber interacts with the materials transmitting them than with each other. This lead to nonlinear effects, the strength of which typically depends on the square (or some higher power) of intensity rather than simply on the amount of light present. Wavelength-division multiplexing (WDM) has gained wide attention in the broadband optical networks and wireless communication in order to utilize the enormous bandwidth of the optical fiber. However, when several optical signals are multiplexed, there arise coupling and crosstalk between the multiplexed signals due to different fiber nonlinear effects, and these phenomena limit the ultimate WDM network performance. Moreover, optical fibers uniquely has relatively low threshold for nonlinear effects [1]. These Interactions in WDM generate new waves under appropriate condition through a variety of Non-linear phenomena such as Stimulated Raman Scattering (SRS), Self-Phase Modulation (SPM), Four Wave Mixing (FWM) and Cross-Phase Modulation (CPM). In a WDM system, these effects place constraints on the spacing between adjacent wavelength channels, and they limit the maximum power per channel, the maximum bit rate, and the system optimum performance [2]. Nonlinearity in optics is an intensity-dependent phenomena which occurs due to change in the refractive index of the medium with optical intensity and inelastic scattering phenomenon. The power dependence of the refractive index is responsible for the Kerr-effect. At high power level, the inelastic scattering phenomenon can induce stimulated effects such as Stimulated Raman-Scattering (SRS). This interactions can be a serious disadvantage in optical communications especially in wavelength-division multiplexing (WDM) systems. The study of non-linearities in optical fibre could be helpful in obtaining nearly the same quality and quantity of output signals as the input signal. How to achieve optimal systems is being studied extensively around the world. However, the complicated interaction between the impairments make the study on the optical fiber communication systems a challenging task. We focus on the study of Stimulated Raman-Scattering (SRS) on the fiber optic communication systems in this paper.

1.1 Stimulated Raman Scattering

Optical waveguides do not always behave as completely linear channels whose increase in output optical power is directly proportional to the input optical power. Several nonlinear effects occur, which in the case of scattering cause disproportionate attenuation, usually at high optical power levels [3]. The most important types of nonlinear scattering within optical fibers are stimulated Brillouin and Raman scattering, both of which are usually only observed at high optical power densities in long single-mode fibers. These scattering mechanisms in fact give optical gain but with a shift in frequency, thus contributing to attenuation

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for light transmission at a specific wavelength. SRS is an example of inelastic scattering, which means that the frequency of the scattered light is downshifted. SRS is the result of interaction between incident light and molecular vibration. Some portion of the incident light is downshifted in frequency by an amount equal to the molecular vibration frequency, which is generally called Stokes frequency [4]. This effect depletes the optical power of the incident light. When there is only a single light wave propagating along the optical fibre.

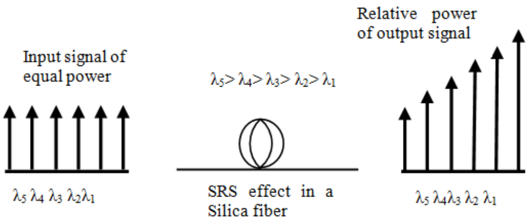

Fig. 1: SRS transfer optical power from shorter wavelengths to longer wavelength

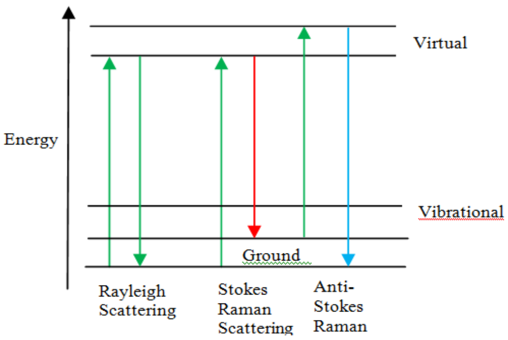

Fig. 2: Stokes and antistokes process

For single channel designs SRS is not usually a problem. It has been shown that the effect of SRS is negligible below 500 mW total power [5]. Given that most fiber optic systems transmit less than 10 mW this might imply that SRS is not a problem. However, for WDM systems each channel will transmit up to 10 mW. Hence the total power of all the channels combined can easily exceed the 500 mW threshold [5].

II. EXPERIMENTAL SETUP

We used OptSim which is an advanced optical communication system simulation software which can be used to design optical communication systems and simulate them to determine their performance, given various component parameters.

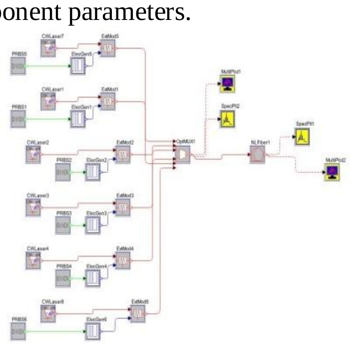

Fig. 3: Experimental setup of SRS

The simulation setup for SRS configuration is shown in figure (3). Block diagram of the system is divided into three section transmitter, channel and receiver. Transmitter section first block is 6 data source where data rate and bit is customized. 6 Electrical driver is to convert binary sequence into electrical pulse. The light carrier is generated by 6 Lorentzian laser source which is further given to 6 Modulator . The modulated signal is further introduced to the optical multiplexer which multiplexed the 6 incoming signal and transmit it to Non Linear optical fiber which is under channel section. In the receiver section two Spectrum Analyzer and an Multiplot is assigned to represent the output. Figure (3) shows how the layout for 6-channel WDM system in Block Mode. Consider 6 wavelength channels and all are having an equal power of 20mW and Equal channel spacing and this is given to the Multiplexer. Then the Multiplexer output is given into the optical fiber. The properties of Optical Fiber (Raman Crosstalk "ON" condition is changed) and the output is seen in optical spectrum having equal order of channel spacing and equal power of 20mW in the 6 laser. Now consider 6 wavelength channels and all are having an equal power of 20mW and unequal Random order channel spacing and this is given to the Multiplexer.

2.1 Stimulated Raman scattering

When high intensity Optical input power is encountered in single mode fiber, the SRS effect will occur. Due to this SRS effect, the minimum power that could be sent through the fiber is reduced. By decreasing the value of input power and by giving unequal channel spacing, the SRS effect is decreased. If the input power level is decreased, the Power Tilt (difference between the lower wavelength channel powers to the higher wavelength channel power in dBm) is also decreased.

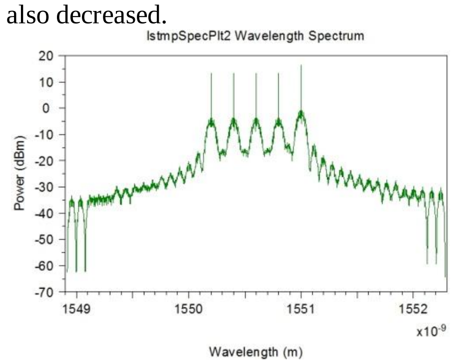

Fig 3.1 Optical spectrum at 20mW power with Equal channel spacing

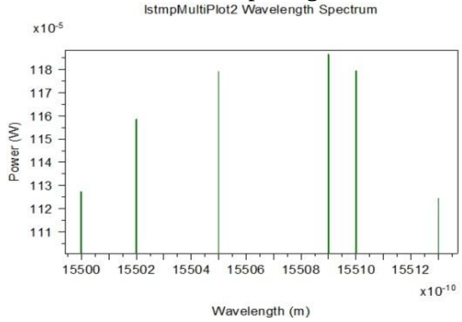

Fig 3.2 Optical spectrum at 20mW power with Unequal channel spacing

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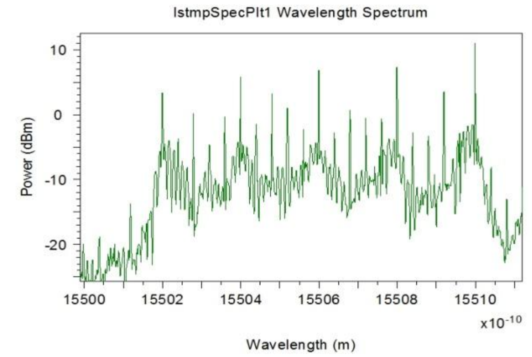

Fig 3.3 Clear view optical spectrum at 20mW power with equal channel spacing

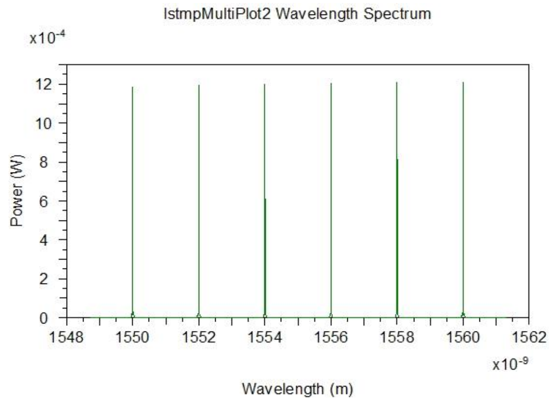

Fig 3.4 Clear view optical spectrum at 20mW power with Unequal channel spacing

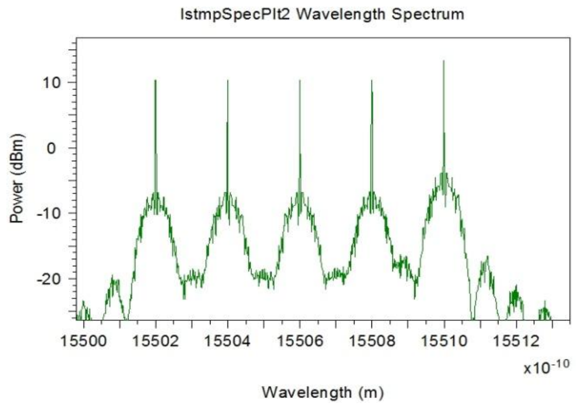

Fig 3.5 Optical spectrum at 50mW power with equal channel spacing

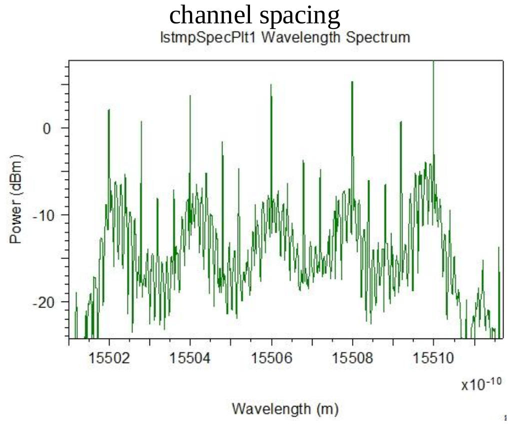

Fig 3.6 Optical spectrum at 50mW power with Unequal channel spacing

In figure 3.1 and 3.2 we had shown spectrum plots for equal and unequal channel spacing. We can clearly see that in figure 3.1 when equal channel spacing was given then there was no tilt in the system seen but when unequal channel spacing was given as shown in figure 3.2 , the power tilt was seen. Figure 3.3 and 3.4 shows the power tilt at 20 mW, equal and unequal channel spacing. Figure 3.5 and 3.6 shows the spectrum for 50mW input power for equal and unequal channel spacing were again we could see the clear power tilt.

III. CONCLUSION

This paper focusses on SRS keeping in objective to reduce effect of the nonlinearities in the system. SRS which causes power to be transferred from lower wavelength channels to higher wavelength channels was investigated. This unwanted Power tilt reduces the optical signal to noise ratio (OSNR) which in turn increases the Bit Error Rate (BER). It was found that the Optical Power tilt decreased with the decrease in input optical power. When the maximum repeater less transmission distance is increased in DWDM systems, then the required optical power level is increased (which will increase the unwanted power tilt). So the optical power level has to be decreased so that optical power tilt should not be increased. Further it was found that unequal channel spacing between channels can reduce the unwanted power tilt value. When the input optical power in the individual channel is increased, then unwanted power tilt were also increased. So unwanted power tilt is reduced by giving minimum input power, however by reducing the input optical power corresponding OSNR is getting reduced. So the input optical power should not be too low or too high. For an ideal system, Power tilt should be zero. Therefore, in order to reduce the Power tilt value, minimum Input power and unequal channel spacing is to be given for the individual channels.

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