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Simulation Analysis of Nonlinear Transmission Impairment in WDM Optical Network

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Abstract: Nonlinear effects are the major degrading sources that occur in nonlinear optical materials such as photonic switch, optical fiber cable. Such kind of interaction between waves causes interaction between channels. FWM (Four-wave Mixing) is one of the major degrading factors in WDM (Wavelength Division Multiplexing)optical network along with other fiber non-linearity. Due to which it is important to investigate the impact of FWM on the design and performance of WDM optical network. In this paper, the effects of FWM with dispersion and polarization being analyzed and simulated on OPTSIM. The simulation results of Input /Output spectrum gives the measure of non-linear variation

Keywords: FWM, WDM, Dispersion, Polarization

I. INTRODUCTION

WDM is widely used for optical communication networks and systems in order to being utilize the maximum bandwidth available for transmission. The fiber non-linearity results severe degradations on the performance of optical communication systems [1]. The non-linearity in optical fibers falls into two categories such as: Inelastic stimulated scattering and Kerr effect. Stimulated scatterings such as Raman and Brillouin are responsible for intensity dependent losses or gains.It is being generated due to stimulated processes. Kerr effect happens due to the change of the refractive index of the fiber with the intensity of the transmitted signal, due to which the signal suffers phase modulation. The nonlinear refractive index is responsible for intensity dependent phase shift of the optical signal[2].One major difference between scattering effects and the Kerr effect is that stimulated scattering have threshold power levels at which the nonlinear effects manifest themselves while the Kerr effect doesn't have such a threshold. Self-Phase Modulation (SPM), Cross-Phase Modulation (XPM) and Four Wave Mixing (FWM) are generated due to optical Kerr effect.

FWM is the major degrading factor in WDM optical communication systems [3].FWM is one of a broad class of harmonic mixing or harmonic generation process, in which three or more waves combine to generate waves at a different frequency that is the sum or difference of the signals that are mixed and generate a fourth EM wave because of the fiber's third order nonlinear susceptibility.

FWM is an intermodulation phenomenon in thenon-linear optics, where the interactions between two wavelengths produce two extra wavelengths in the signal [4]. It is similar to the existence of third-order intercept point in electrical systems. FWM is a weak effect, but it accumulates, if the signals in the optical channels remain in phase with each other over long transmission distances. Pulses transmitted over different optical channels, having different wavelengths, they will stay in the same relative positions along the length of the fiber because the signals experience near-zero dispersion [5].This further magnifies at zero dispersion wavelength. FWM gives birth to new waves of the frequency:

$$f_{ijk} = f_i + f_j - f_k$$

For a WDM system with N channels the number of four-wave mixing products i.e.M will be given as:

$$M = \frac{1}{2}\left(N^3 - N^2\right)$$

Here N is number of channels transmitted.

Thus in FWM effect, three co-propagating waves(N=4) produce nine new optical sideband waves(M=24) at different frequencies. This new frequency falls in the transmission window of the original frequencies that leads to severe cross talk between the channels propagating through an optical fiber[6]. Moreover, the degradation becomes more severe for large number of WDM channels having small channel spacing. Table I shows the performance parameters of FWM.

TABLE I
PERFORMANCE PARAMETERS OF FWM

Sr.No.	Components	Parameters	Numerical Values
1	Optical combiner	Attenuation on each output	0.9515dB
2	Booster	Output Power	4mW
3	Optical Fiber	Length	150KM
4	In Line Optical Amplifier	Gain	30dB
5	Pre Amplifier	Gain	30dB
6	Polarizer	Number of rotations	1
7	Fiber Grating Compensator	Reference frequency & Reference wavelength	193.05THz &1552.9264 nm

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II. FWM WITH DISPERSION

A model of WDM optical communication network for dispersion is simulated using OPTSIM to illustrate the non-linear variations in FWM as shown in Fig.1.In this two WDM channel transmitter is required at the input side. WDM transmitter is composed of following blocks: data source, driver, laser source and amplitude modulator. The output of transmitter is applied to the optical combiner with attenuation on each output 0.91515dB. Then this output is connected to the booster having output power of 4mW or 6.0206dBm.Booster is an optical amplifier fixed output power device. This output of booster is connected to optical splitter through which input optical spectrum analyser is being connected. In the input spectrum analyser number of spectrum points over the simulation are 3000.This splitter output goes to the fiber link which is of 150KM in length and length statistical variation is 0.0,thenthis output of fiber link is connected to fiber grating compensator. In this ideal fiber grating compensator is used which compensates the fiber dispersion at each span. The output of fiber grating meets with the In-line optical amplifier which is a fixed gain amplifier. Gain for In-line optical amplifier is 30dB,then this is further connected to optical fiber of length 150km and ideal fiber grating compensator having reference frequency of 193.05THz and reference wavelength of 1552.9264 nm which is further in connection with Pre-amplifier of gain 30dB and optical splitter whose attenuation of each output is 0.91515dB. This splitter output is connected with output spectrum analyser which has 1500 number of spectrum points over the simulation.

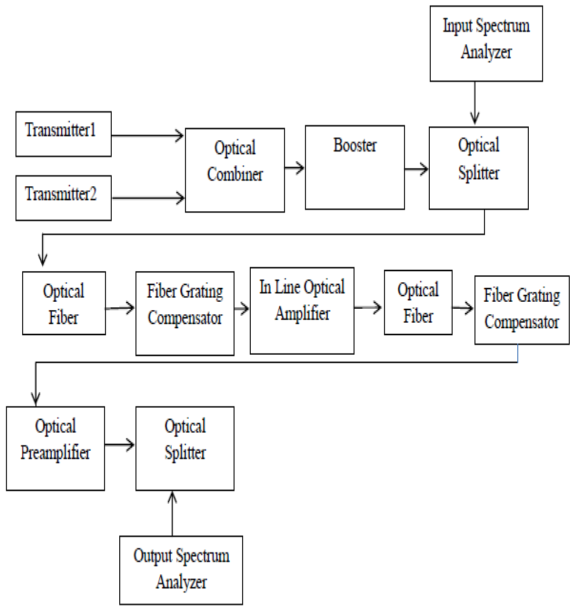

Fig.1 Block Diagram of FWM with Dispersion

A model of WDM optical communication network for polarization is simulated using OPTSIM to illustrate the non-linear variations in FWM as shown in Fig.2.In this two WDM channel transmitter is required at the input side. WDM transmitter is composed of following blocks: data source, driver, laser source and amplitude modulator. Polarization rotator of having number of polarization=1 and 1st Rotation="Axis-S2" is applied at the output of the amplitude modulator. The output is applied to the optical combiner with attenuation on each output is 0.91515dB. Then this output is connected to the booster having output power of 4.0mW or 6.0206dBm.Booster is an optical amplifier fixed output power device. This output of booster is connected to optical splitter through which input optical spectrum analyser is being connected. In the input spectrum analyser number of spectrum points over the simulation is 3000.This splitter output goes to the fiber link which is of 150KM in length this output of fiber link is connected to fiber grating compensator. In this ideal fiber grating compensator is used which compensates the fiber dispersion at each span. The output of fiber grating meets with the In-line Optical Amplifier which is a optical amplifier of fixed gain. Gain for In-line optical amplifier is 30dB,then this is further connected to optical fiber of length 150km and ideal fiber grating compensator having reference frequency of 193.05THz and reference wavelength of 1552.9264nm which is further in connection with Pre-amplifier of gain 30dB and optical splitter whose attenuation of each output is 0.91515dB. This splitter output is connected with output spectrum analyser which has 1500 number of spectrum points over the simulation.

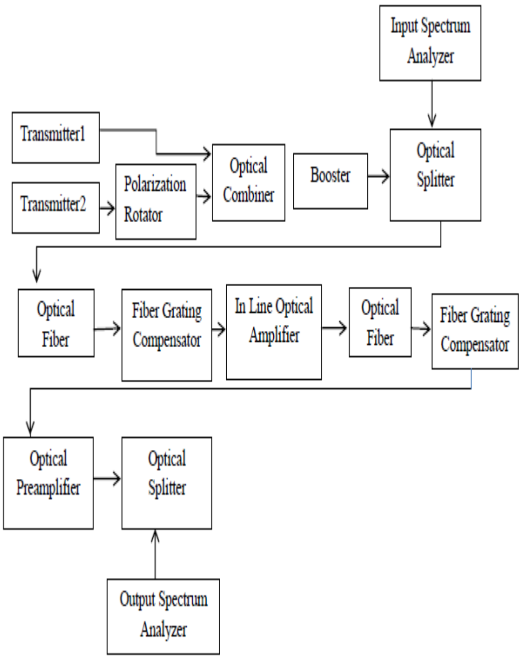

Fig.2 Block Diagram of FWM with Polarization

III. SIMULATION RESULTS FOR FWM AND DISPERSION

Two WDM channels are launched over two DS fiber spans of 150KM, each Dispersion is completely compensated at each span. The results are quoted in Fig.3(a), Fig.3(b) and Fig.3(c). Fig. 3(a) shows optical power spectrum at the fiber input in the range of 192.90THz to 193.20 THz. Fig.3 (b) shows the optical power spectrum at the output for different setting of dispersion in the range of 192.90THz to 193.20THz. The spectrum of the superimposed signals of input spectrum and output spectrum clears that FWM products decrease with increasing dispersion in the range of 192.90THz to 193.90 THz as shown in Fig.3(c).

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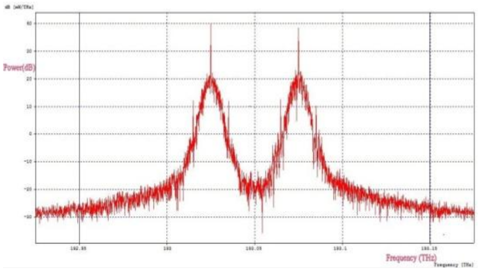

Fig.3 (a) Input Optical Spectrum

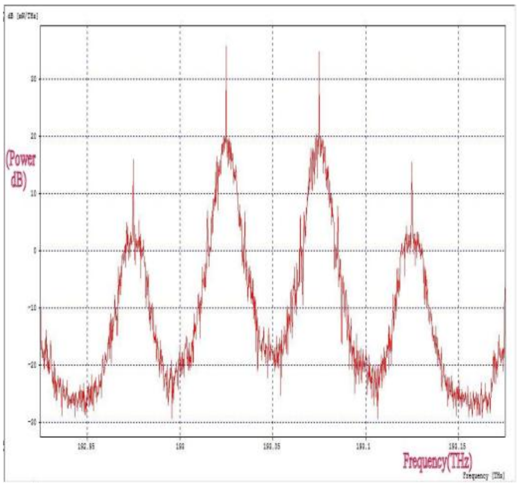

Fig.3 (b) Output Optical Spectrum

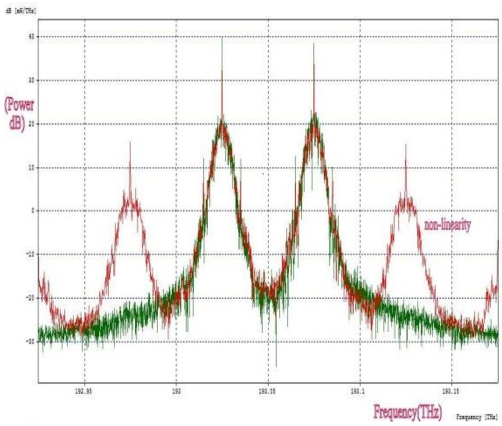

Fig.3(c) Superimposition of Optical Spectrums

IV. SIMULATION RESULTS FOR FWM AND POLARIZATION

Two WDM channels are launched over two DS fiber spans of 150KMeach.The lasers representing the two channels have the same initial polarization (along the x axis), but polarization for one source is rotated around the S2 axis and number of roation =1 through parametric runs. The FWM products are maximized when the polarizations are aligned and completely reduced to zero when the two polarizations are orthogonal. The results are quoted in Fig.4 (a), Fig.4 (b) and Fig.4 (c). Fig. 4(a) shows optical power spectrum at the fiber input in the range of 192.90THz to 193.20THz and Fig. 4(b) shows the optical power spectrum at the fiber output tin the range of 192.90 THz to 193.20THz. the spectrum of the superimposed signal of input optical spectrum and output optical spectrum makes clears that FWM products decrease with increasing polarization in the range of 192.90THz to 193.20THz as shown in Fig.4(c) but these variations are very smaller as compared to that of dispersion.

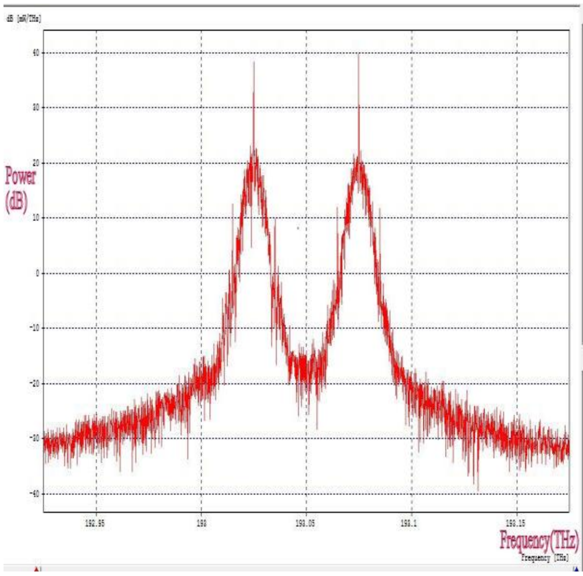

Fig.4 (a) Input Optical Spectrum

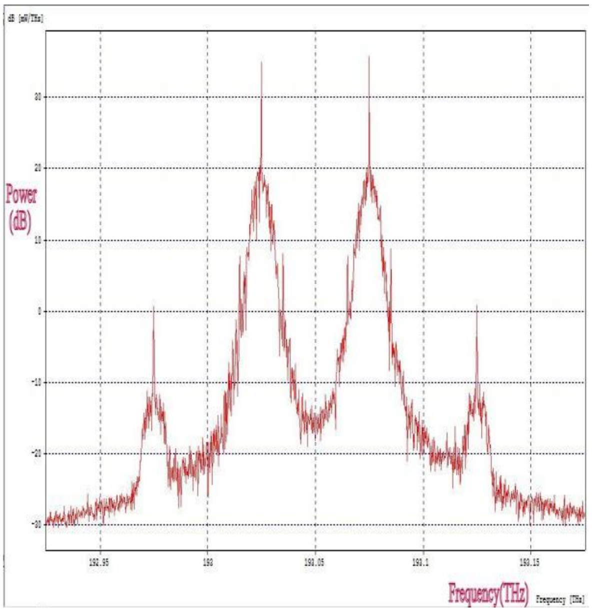

Fig.4 (b) Output Optical Spectrum

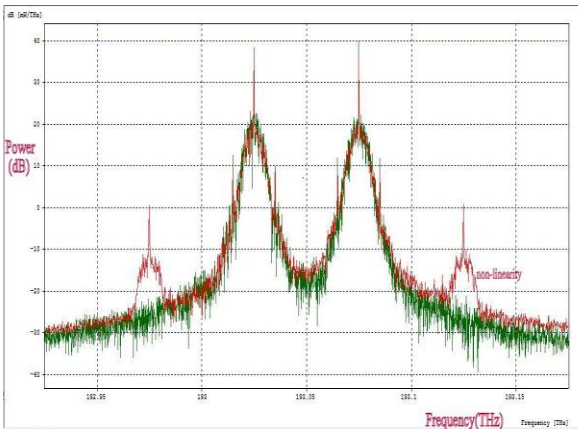

Fig.4(c) Superimposition of Optical Spectrums

V. CONCLUSION

This paper being simulated on the OPTSIM and gives the variations caused by dispersion and polarization in FWM system.FWM with dispersion causes larger scale variations in FWM product as compared to FWM with polarization when considering the same parameters. Hence it is preferred to use FWM with polarization as it causes lesser distortions and variations as compared to variations observed on FWM with Dispersion.

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