Comprehensive Study of Non-Linear Effects in WDM Optical Networks

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ABSTRACT
The performance of optical components such as photonic switch, OXC, Optical Amplifiers is degraded by the presence of Non-linear effects in Optical networks. Four-wave Mixing (FWM) is the main deteriorating factor in WDM (Wavelength Division Multiplexing) Optical Network. It is necessary to study the impact of FWM on the performance of WDM networks. In this paper, we study the effects of FWM along with Dispersion and Polarization in WDM networks. The simulation is done using OPTSIM and the results of input and output spectrum gives the amount of Non-linearity in WDM Optical Network.

Keywords
Wavelength Division Multiplexing (WDM), Four-Wave Mixing (FWM), Dispersion, and Polarization.

1. INTRODUCTION
WDM is used in optical communication networks to obtain maximum utilization of bandwidth. But the nonlinear effects of the fiber degrade the performance of optical networks[4]. The nonlinear effects can be classified into two categories namely (a) Stimulated Scattering and (b) Quadratic electro-optic effect (QEO).

Stimulated scattering such as Raman and Brillouin is the interaction of light waves with the molecules of the fiber to release a phonon at Acoustic frequency and higher frequency.QEO effect is the change in the RI of the fiber w.r.t. the light waves resulting in phase modulation of the signal. Four-wave mixing (FWM), Self phase Modulation (SPM) and Modulation intensity are due to QEO effect. FWM is the intermodulation in which three or more frequencies combine to generate a fourth frequency which is the addition or subtraction of the signals. Initially FWM is very negligible, but gains momentum if the signal in the channel remain in phase over long distances of transmission. If fa, fb, fc are the three different frequencies, then the new frequency is[1,2]:

$$f_{abc} = f_a + f_b - f_c \quad \text{where } a,b \neq c$$

FWM causes cross talk between different wavelength channels and power imbalance in the channels. This is suppressed by avoiding equidistant channel spacing. For a M-channel WDM system, the number of Four-wave mixing products is given by [3].

$$F = 1/2\ (M^3 - M^2).$$

Degradation increases as the number of WDM channels increases with small channel spacing.

2. FWM WITH DISPERSION
A WDM model for dispersion using OPTSIM is as shown in fig1. The input consists of 2 WDM channel transmitter which comprises of Source data, driver, laser beam source and Amplitude Modulator. The output of the transmitter is applied to the optical combiner with attenuation of 0.92dB on each output. This is then connected to a booster which is an amplifier with an output power of 5mW. The output booster is connected to an optical splitter which in turn is connected to an input spectrum analyzer [4] .

The number of spectrum points for simulation of the input spectrum analyzer is 3000. The splitter is connected to a fiber-link of length 160Km which is in turn connected to a fiber grating compensator[5]. This fiber grating compensator is used to compensate fiber dispersion at various stages. The output of fiber grating compensator is connected to in-line optical Amplifier whose gain is 40dB. This is again connected to a fiber-link of length 160Km and a fiber grating compensator whose reference frequency is 194THz and reference wavelength is 1553n. This is again connected to a preamplifier of gain 40dB and an optical splitter whose output attenuation is 0.92dB. The output of Splitter is connected to an output spectrum analyzer which has 2000 number of spectrum points for simulation [6].

Table 1. Performance parameters of FWM

Sl.	Components	Parameters	Numerical Values
1	Optical Combiner	Attenuation on each output	0.92dB
2	Booster	Output Power	5mW
3	Optical Fiber	Length	160Km
4	In line Optical Amplifier	Gain	40dB
5	Pre-Amplifier	Gain	40dB
6	Polarizer	Number of Rotations	1
7	Fiber Grating Compensator	Ref. Frequency & Ref. Wavelength	194THz & 1553 nm

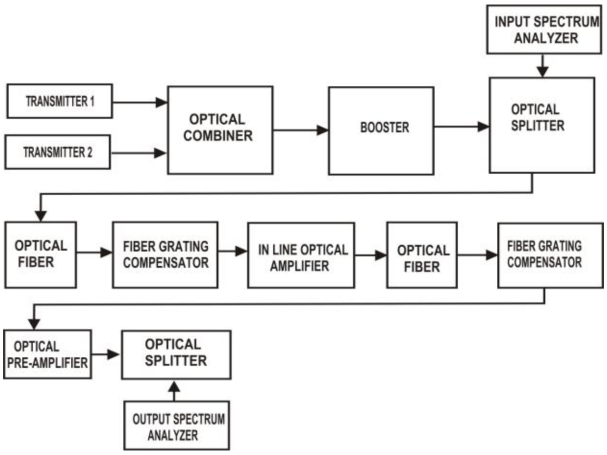

Figure 1. Block diagram of FWM with Dispersion

3. FWM WITH POLARIZATION

A WDM model for polarization using OPTSIM is as shown in fig2. The input consists of 2 WDM channel transmitter comprising Source data, driver, laser beam source and Amplitude Modulator. Polarization Rotator which has number of polarization =1 and 1st Rotation = S2-axis is applied to Amplitude Modulator. The output of polarization rotator and transmitter1 is applied to the optical combiner whose attenuation is 0.92dB[7]. The output of combiner is then connected to the booster having power of 5mW.The output of booster is then connected to an optical splitter which is in turn connected to an input spectrum analyzer possessing 3000 spectrum points for simulation. This splitter is connected to a fiber-link of length 160Km which is in turn connected to a fiber grating compensator. The output of fiber grating compensator is connected to an In-line optical Amplifier whose gain is 40dB[8]. This is again connected to a fiber-link of length 160Km and a fiber grating compensator whose reference frequency is 194THz and reference wavelength is 1553n [9,10]. This is again connected to a preamplifier of gain 40dB and an optical splitter whose output attenuation is 0.92dB[11].The output of Splitter is connected to an output spectrum analyzer which has 2000 number of spectrum points for simulation[12].

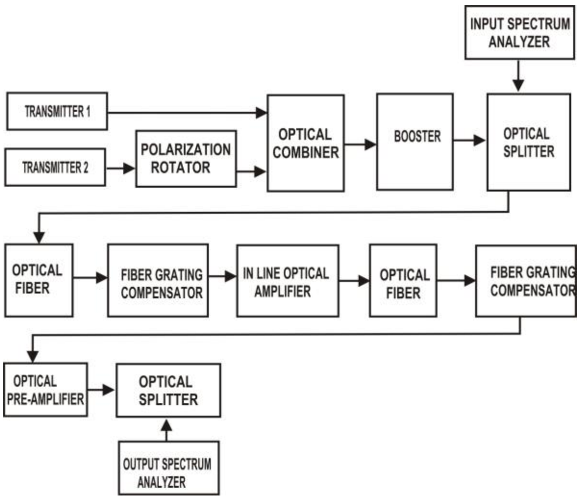

Figure 2. Block diagram of FWM with Polarization

4. SIMULATION AND RESULTS

4.1 FWM with Dispersion

Two WDM channels are launched over 2 Dispersion Shifted fiber spanning over 160Km each. Fig3 (a) shows the fiber input optical spectrum in the range 193THz to 193.5THz. Fig3 (b) shows the fiber output optical spectrum in the range 193THz to 193.5THz.

Fig3 (c) shows the spectrum of the superimposing waves of input spectrum and output spectrum. We see that FWM products decrease with increase in dispersion over the range 193THz to 193.5THz.

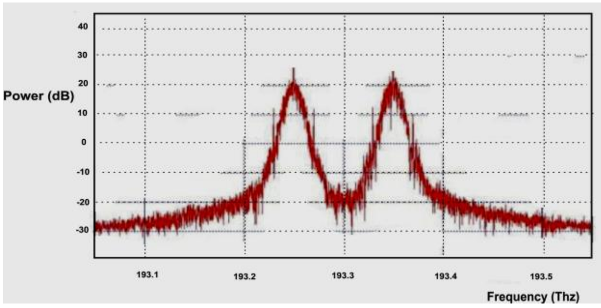

Figure 3(a). Input Optical Spectrum

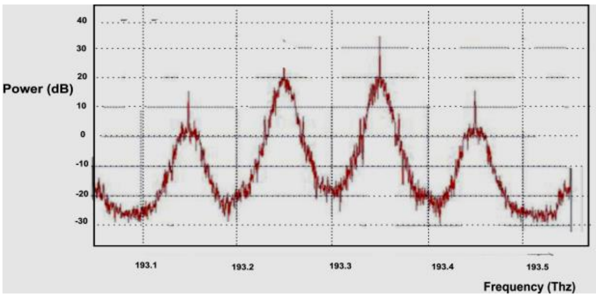

Figure 3(b). Output Optical Spectrum

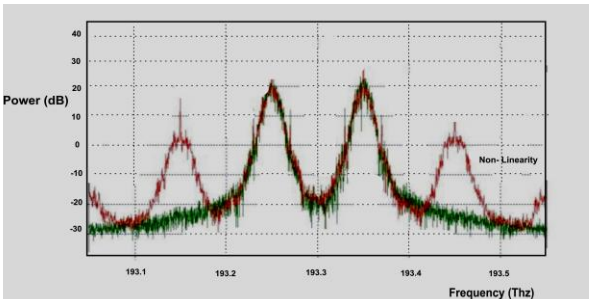

Figure 3c). Superimposition of Optical Spectrum

4.2 FWM with Polarization

Two WDM channels are launched over 2 Dispersion Shifted fiber spanning over 160Km each. The 2 channels have the same initial polarization, but the polarization for one source is rotated around S2-axis and the number of rotation = 1. FWM products are Maximum when the 2 polarizations are parallel and the FWM products are reduced to zero when the 2 polarizations are perpendicular to each other. Fig4 (a) shows the fiber input optical spectrum in the range 193THz to 193.5THz. Fig4 (b) shows the fiber output optical spectrum in the range 193THz to 193.5THz. Fig 4(c) shows the spectrum of the superimposing waves of input spectrum and output spectrum. The FWM products decrease with increase in polarization over the range 193THz to 193.5THz. These fluctuations are very negligible compared to that of dispersion.

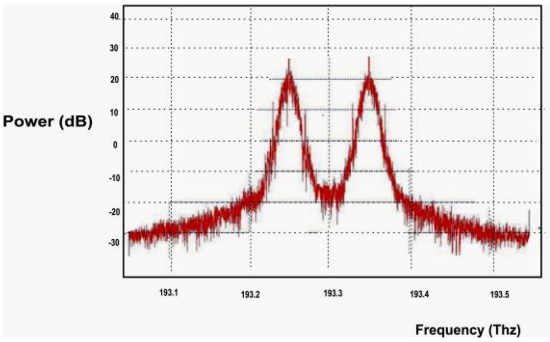

Figure 4(a). Input Optical Spectrum

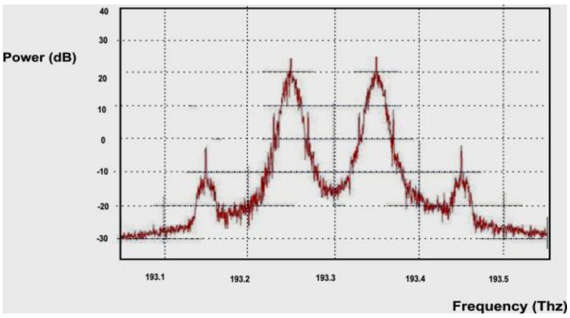

Figure 4(b). Output Optical Spectrum

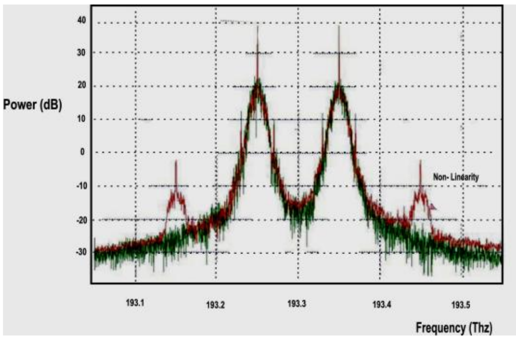

Figure 4(c). Superimposition of Optical Spectrum

5. CONCLUSION AND FUTURE SCOPE

This paper brings the variations caused by dispersion and polarization of FWM in WDM networks using OPTSIM. FWM with dispersion causes larger variations when compared to FWM with polarization. Hence FWM with polarization is much preferred since it produces less distortion and variations as compared to FWM with dispersion. We have investigated the effect of FWM for only two channels. In future we can implement the same to more channels and optimization of the design can be achieved for higher bit rate.

6. REFERENCES

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