Chromatic Dispersion Compensation for 16×10 Gbps WDM Optical Communication System with Non Linearity

Darshan D. Patel and Rohit B.Patel

Abstract: **In order to expand the capacity of optical fiber communication system the most important phenomena is the emergence of wavelength division multiplexing (WDM). Using WDM, 16 channels of information can be transmitted on single fiber. There are some limiting factors related to data rate and capacity in WDM optical fiber communication system. These limiting factors can be linear or non-linear.**

The non linear effects are SPM,XPM,FWM,SBS and SRS,Self phase modulation (SPM), Stimulated brillouin scattering (SBS) occurs only in single channel fiber optics communication system and Cross phase modulation (XPM), Four wave mixing (FWM), Stimulated Raman scattering (SRS) have impact on multichannel WDM fiber communication system. In this paper we show the effect of XPM,FWM and SRS on WDM optical communication system.We also describe some novel technique to reduce the effect of these non linearities (XPM, FWM, and SRS) in WDM fiber communication system.

Keywords:**WDM, Cross phase modulation, Four wave mixing, Stimulated Raman scattering.**

INTRODUCTION

Non-linearity's in fiber arose as the number of data channel, transmission length, data rate & power level increase. Mainly non-linearity occurs in fiber because of dependence of refractive index on power going through fiber. This Phenomena is shown by equation (1)

$n=n_o+n_2(P/A_{eff})$ ……………………………………….. (1)

The brief introduction of XPM, FWM & SRS is given below

Cross phase modulation (XPM)

Cross-phase modulation (XPM) is an example of fiber nonlinear effects which can limit the distance and the capacity of WDM optical fiber transmissions. When a single optical pulse transmit through the optical fiber, then because of refractive index dependence on power, the leading edge of pulse cause increase in refractive index & its trailing edge cause decrease in refractive index. Leading edge of pulse shift toward longer wavelength and trailing edge toward shorter wavelength. This phenomenon called self phase modulation, causes overall spreading of pulse. In case of multiple pulse travel in the fiber as in WDM communication system, multiple pulses overlap to cause cross phase modulation. Distortion & pulse broadening is caused by cross phase modulation.

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Four wave mixing (FWM)

This non linear effect arises when two or more pulses transmit through same fiber. Generally FWM effect occur if the three light pulses, having different wavelength & traveling through single fiber, interact together to generate a new pulse.

If the three wavelength $\lambda_{A,}$ $\lambda_{B\,\&}$ λ_C are propagating through single fiber, these wavelengths will interact according to equation (2) to generate new λ_D

$\lambda_{D=}\lambda_A\pm\lambda_B\pm\lambda_C$…………………………………………………………………….(2)

Here A≠B≠C

In general, the number of crossing product K, for M number of input channel is given by equation (3)

K=[M^2*(N-1)]…………………………………………(3)

Equation (3) shows that non linear effect FWM increase as a number of channels in WDM system increase.

Stimulated Raman scattering (SRS)

Stimulated Raman scattering (SRS) is the ultimate performance limiting phenomenon in multichannel optical Transmission systems [6].Among the WDM channels, stimulated Raman scattering (SRS) causes a power transfer from shorter wavelength channels to longer wavelength channels [7].When intense beam of light of high power level, which is usually called pump, propagates in the optical fiber, then interaction between vibration of molecules of SiO2 and light cause stimulated Raman scattering. This effect primarily affects the power distribution of the input data channels and leads to channel to channel crosstalk [8].

SIMULATION OF CROSS PHASE MODULATION (XPM)

Our proposed algorithm (shown in figure 1) consists of WDM transmitter, WDM receiver, optical fiber, ideal dispersion compensating FBG and bit error rate analyzer to analyze the output result. In order to analyze the impact of XPM on optical fiber communication system at various power levels, we vary the input power & number of channel of WDM transmitter.

The optical transmission link in our algorithm is such designed that the transmission link consist 70 Km single mode fiber (SMF) with dispersion of 17 ps/nm/Km followed by 16 Km long dispersion compensating fiber (DCF) with dispersion of -72 ps/nm/km (shown in figure 1). One Optical amplifier (OA) with gain of 18 dB & zero noise figure is used after DCF. NRZ nodulation type is used. Link is operating at 10Gbps. For the visualization of BER, Q factor & eye diagram, BER analyzer is used. Channels spacing is 100 GHz.

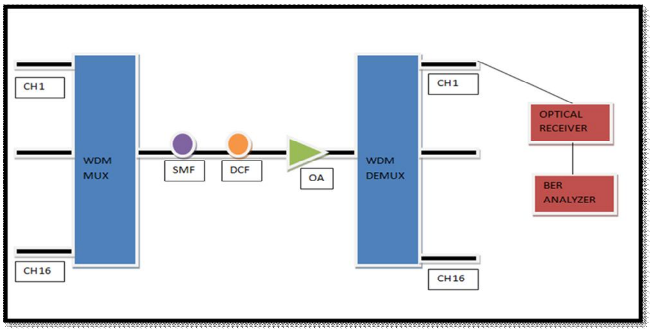

Fig. 1. 16 Channel WDM link

SIMULATION RESULT

RESULT 1

In this simulation we analyze the effect of power on cross phase modulation effect. The figure 2 shows how bit error rate increase with increase in power. The table 1.1 shows power and BER values.

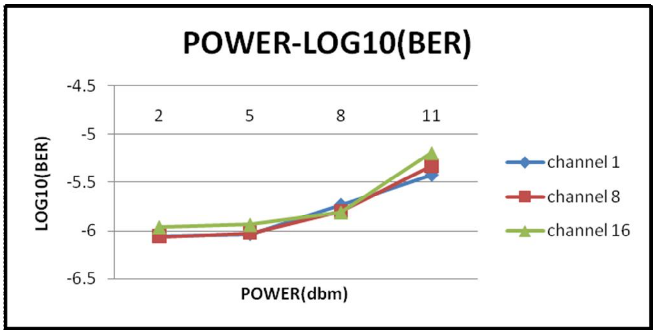

Fig. 2. POWER-LOG10 (BER)

TABLE 1.1

POWER (dbm)	BER (CH 1)	BER (CH 2)	BER (CH 3)
2	8.7097E-7	8.6658E-7	1.0839E-6
5	9.1897E-7	9.4710E-7	1.1446E-6
8	1.8533E-6	1.5782E-6	1.5414E-6
11	3.7827E-6	4.6681E-6	6.4071E-6

RESULT 2

In this simulation we analyze the effect of number of channel on cross phase modulation effect. The figure 3 shows how bit error rate increase with increase in number of channels. In this simulation we vary the no of channel in system and kept the power constant 5 dbm.

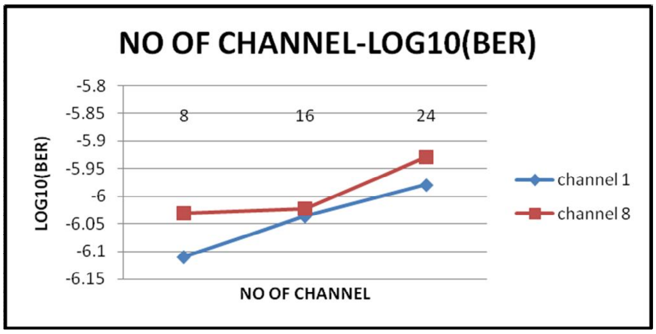

Fig. 3. NO OF CHANNEL-LOG10 (BER)

CROSS PHASE MODULATION COMPENSATION

In order to make WDM system effective for long distance communication, it is necessary to reduce the non linear Cross phase modulation effect. The penalty arising from XPM can be effectively decreased by dispersion management technique & increasing channel spacing.

PART 1

For the circuit shown in figure 1, Replace DCF by ideal dispersion compensating FBG and block diagram look as shown in figure 4 below

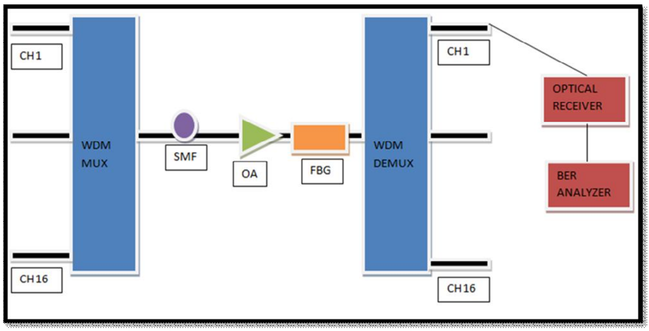

Fig. 4. 16 Channel WDM link using FBG

By using ideal dispersion compensating FBG we are able to compensate effect of cross phase modulation. The below figure 5 and figure 6 shows how cross phase modulation effect is reduced by using ideal dispersion compensating FBG. The table 1.2 and table 1.3 shows power and BER values for channel 1 and channel 16 by using DCF and using FBG.

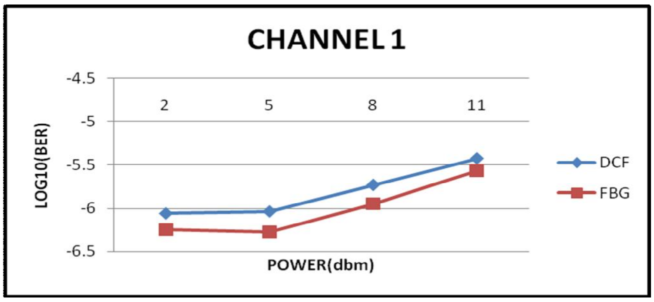

Fig. 5. Channel 1 POWER-LOG10 (BER)

TABLE 1.2

POWER (dbm)	DCF(BER) (CH 1)	FBG(BER) (CH 1)
2	8.7097E-7	5.6815E-7
3	9.1897E-7	5.2760E-7
8	1.8533E-6	1.1212E-6
11	3.7827E-6	2.7289E-6

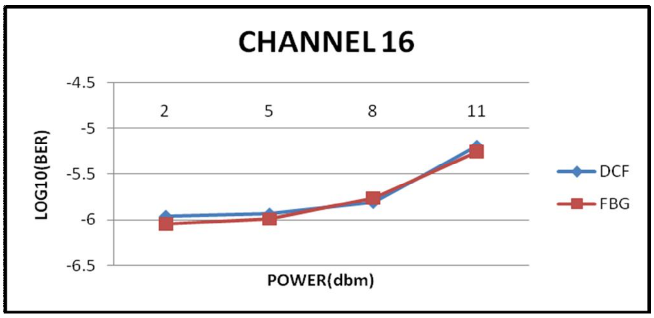

Fig. 6. Channel 16 POWER-LOG10 (BER)

TABLE 1.3

POWER (dbm)	DCF(BER) (CH 16)	FBG(BER) (CH 16)
2	1.0839E-6	8.9741E-7
3	1.1446E-6	1.0162E-6
8	1.5414E-6	1.7259E-6
11	6.4071E-6	5.5408E-6

So from figure 5 & figure 6 and table 1.2, table 1.3 we can see that by using ideal dispersion compensating FBG the BER of fiber system decreased & Quality factor increased, so we reduce XPM effect.

SIMULATION OF FOUR WAVE MIXING (FWM) EFFECT

For analyzing the effect of FWM on 8 channel WDM fiber communication system, Transmission link consist 70 Km SMF followed by 16Km DCF. After DCF an optical amplifier with 25 dB gain is used. Dispersion of SMF is 17 ps/nm/Km & DCF is -72 ps/nm/Km.Channel spacing is 100 GHz. NRZ modulation type is used. Input power is -8 dbm and Optical spectrum analyzer is used to analyze the spectrum at input & output.

Spectrum of input signal is measured after the WDM multiplexer, and after optical amplifier the output signal spectrum is measured by Optical spectrum analyzer.

For 8 input channels & -8 dbm input power, spectrum of input & output signal is shown below in figure 7 & figure 8 respectively.

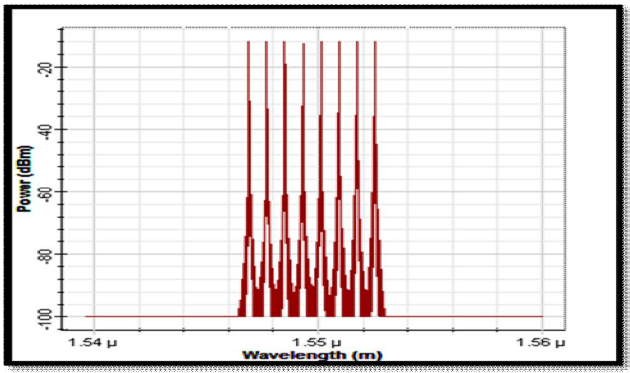

Fig. 7. Input spectrum of 8 channel WDM system

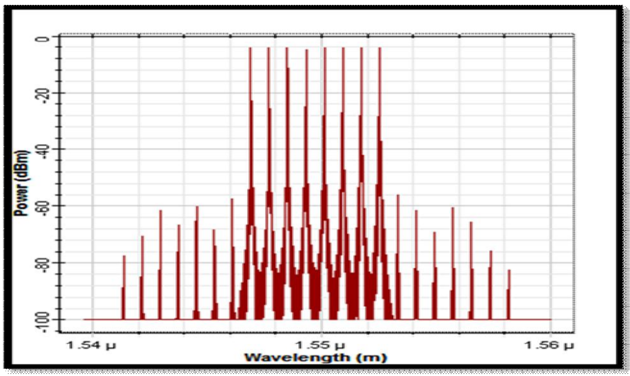

Fig. 8. Output spectrum of 8 channel WDM system

FOUR WAVE MIXING COMPENSATION

Rectangular optical filter can be very much effective to compensate the four wave mixing effect. For optical fiber communication system whose output is shown in figure 8, in that system, if we use Rectangular optical filter after optical amplifier. Bandwidth of Rectangular optical filter is set 800 GHz & central frequency is 193.35 GHz. The output of this modified circuit is shown in figure 9.

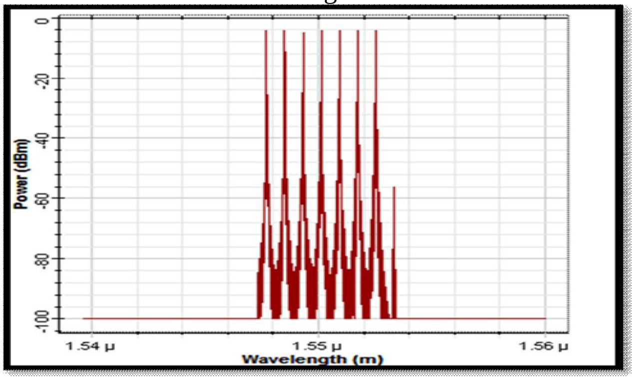

Fig. 9. Output spectrum of 8 channel WDM system after using Rectangular optical filter

By comparing figure 8 & figure 9, we can conclude that FWM can be completely removed by Rectangular optical filter. Rectangular optical filter did not reduce the output power.

SIMULATION OF STIMULATED RAMAN SCATTERING

System which we selected for analysis of SRS consists of CW lasers for input, ideal WDM multiplexer, optical fiber and optical spectrum analyzer to observe the output result. For SRS analysis in optical fiber communication system at various power levels, we vary the number of channels and power by keeping length of fiber unchanged.

We design our system such that length of optical fiber which we selected is 0.2 km. Channel spacing is not constant it varies from one channel to other. We keep the power of first input channel greater than all of other remaining input channels.

If we have 16 WDM input data channels and power of first channel is 100 W and -99 dbm of each of remaining 15 channels, then input signal spectrum after WDM Mux and output signal spectrum after fiber are shown in figure 10 & figure11 respectively.

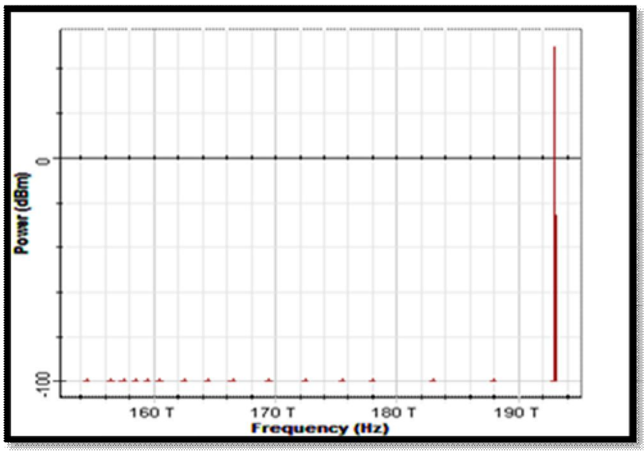

Fig. 10. Input spectrum of 16 channel WDM system

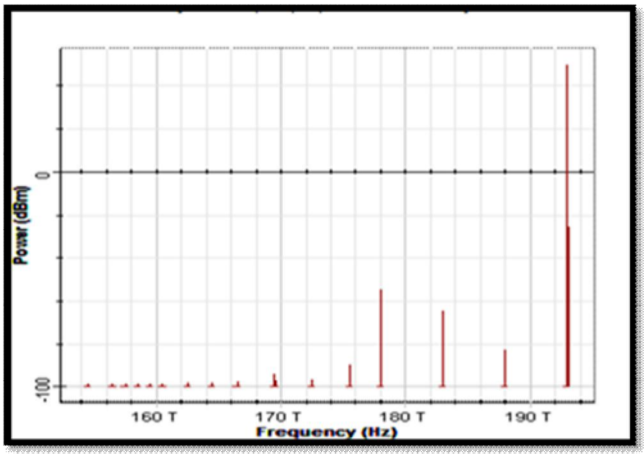

Fig. 11. Output spectrum of 16 channel WDM system

To analyze the effect of stimulated raman scattering non linear effect we do another simulation which have 22 input channels, power of first channel is 150 W and -99 dbm of each remaining channels. The figure 12 shows the input spectrum of 22 channel WDM system and figure 13 shows the output spectrum of 22 channel WDM system. The figure 13 shows the SRS effects.

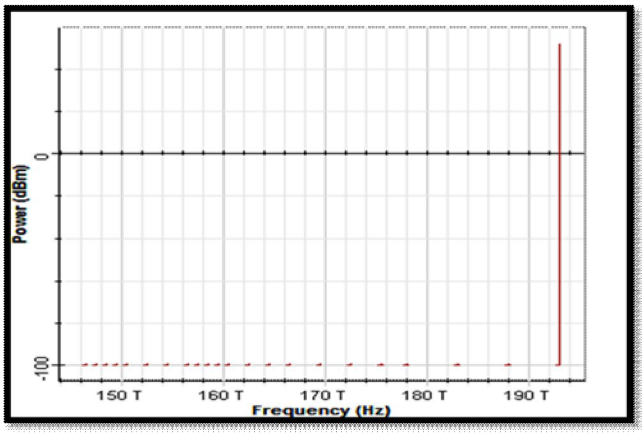

Fig. 12. Input spectrum of 22 channel WDM system

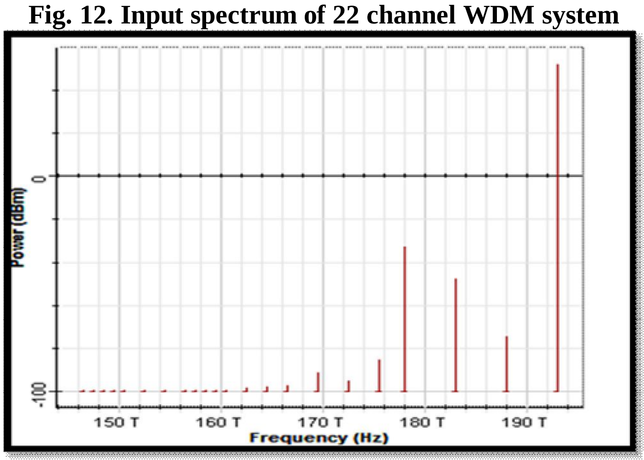

Fig. 13. Output spectrum of 22 channel WDM system

Comparing the output spectrum shown in figure 11 & figure 13, we conclude that SRS affect increase with increase in power & number of input channels. By increasing the effective area of fiber we can reduce SRS in fiber communication system.

CONCLUSION

This paper briefly presents the analysis of XPM, FWM and SRS effect in 16 channels WDM fiber optics communication system. The analysis is done on the basis of result obtained from simulation. In this paper we show how the non linearity's i.e. XPM increase in optical fiber communication system by increasing the input power and number of input channels we compensate the effect of XPM using FBG, we also analyze the effect of FWM and reduce the effect of FWM using rectangular optical filter and we show the effect of SRS Currently the work is underway, on efficient compensation of SRS.

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