ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 6, June 2013

Effect of Chromatic Dispersion on FWM in Optical WDM Transmission System

Priyanka Dalotra[1], Hardeep Singh[2]

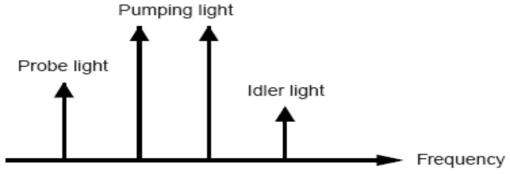
Student, M.E. ECE, Thapar University, Patiala, India[1]

Asst. Professor Dept. of E.C.E., Thapar University, Patiala, India[2]

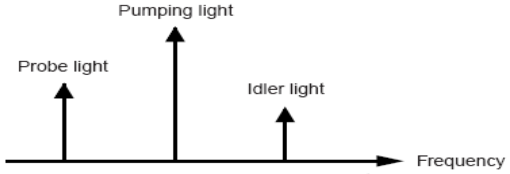
Abstract: FWM can limit the system performance by inducing a crosstalk in long haul multi-channel WDM system. Chromatic dispersion which broadens the pulse, also comes into picture while transmission. This paper shows the effect of chromatic dispersion on FWM in terms of input/output spectrums and eye diagrams. Results show that FWM reduces by using unequal channel spacing and this reduction is more when the dispersion coefficient is increased.
.

I INTRODUCTION

Four wave mixing causes serious problems in wavelength division multiplexed systems [1]. FWM may induce lightpath BER fluctuations in dynamic networks that can affect the optical signal to noise ratio and quality of service in transparent networks under highly complex nonlinear effect [2]. Four-wave mixing (FWM) is a parametric process in which different frequencies interact and by frequency mixing generate new spectral components [3]. Four-wave mixing (FWM) is a type of optical Kerr effect, and occurs when light of two or more different wavelengths is launched into a fiber. Generally speaking FWM occurs when light of three different wavelengths is launched into a fiber, giving rise to a new wave (known as an idler), the wavelength of which does not coincide with any of the others. Fig.1 shows the four wave mixing in frequency domain.



a) 2-channel pump wave



b) 1-channel pump wave (degenerated FWM)

Fig.**1**. Schematic of four wave mixing in frequency domain [4]

II THEORETICAL ANALYSIS

The idler frequency may then be determined by: $f\text{idler} = f\text{p}1 + f\text{p}2 - f\text{probe}$

where, f_{p1} and f_{p2} are the pumping light frequencies, and f_{probe} is the frequency of the probe light [5, 6]. This condition is called the frequency phase-matching condition. The FWM power generated at the end of the fiber due to interaction of channels at frequencies, f_i, f_j and f_k is given by

$P_{FWM} = ((1024\pi^6)/(\eta^4\lambda^2c^2))[D\chi]^2((P_iP_jP_k)$
$/(A_{eff}^2))L_{eff}^2\eta e^{\alpha L}$

where Pi, Pj and Pk, refer to the soliton input powers at frequency fi, fj and fk respectively, n is the fiber effective refractive index, λ is the zero dispersion wavelength, c is the velocity of light, χ is the 3rd order nonlinear susceptibility of the single mode fiber, Aeff is the effective mode area of the fiber, Leff is the fiber effective length, a is fiber attenuation coefficient and D is the degeneracy factor, where D = 6 for i = j and D = 3 for i ≠ j.

The FWM light generation efficiency is given by

$\eta = (\eta^2/M^2(\alpha^2+\Delta\beta^2)))\ ((\sin^2(M\Delta\beta L_{a/2}))/$
$(\sin(\Delta\beta L_{a/2}))).(1+(4\exp(-\alpha L_a)\sin^2$
$(\Delta\beta L_{a/2}))/(1-\exp(-\alpha L_a))^2$

where M refers to the number of fiber sections and Δβ, the phase mismatching constant, in general, can be written as $\Delta\beta = \beta\ (f_i) + \beta\ (f_j) - \beta\ (f_k) - \beta\ (f_{FWM})$ where β represents the propagation constant [7].

III CHROMATIC DISPERSION

Chromatic dispersion results from the spectral width of the emitter. The spectral width determines the number of different wavelengths that are emitted from the LED or laser. The smaller the spectral width, fewer are the number of wavelengths that are emitted. Longer wavelengths will arrive at the end of the fiber ahead of shorter ones, spreading out the signal. Long haul communication system can be designed by wavelength division multiplexing of high bit rate per channels. In such all-optical systems the effect of chromatic dispersion and nonlinearities accumulate during light propagation imposing limits on the achievable performance.

Fig.2. Pulse broadening due to chromatic dispersion

Chromatic dispersion, which broadens the pulses, shown in fig.2, can be reduced by using dispersion shifted fibers (DSFs) at 1550-nm wavelength range, but low chromatic dispersion enhances some nonlinear effects of fibers like four wave mixing [8,9]. One of the ways to suppress FWM is increasing the channel spacing. This increases the group velocity mismatch between channels. This has the drawback of increasing the overall system bandwidth, requiring the optical amplifiers to be flat over a wider bandwidth and increasing the penalty due to stimulated Raman Scattering (SRS). Also, in WDM and DWDM systems, to meet the increasing traffic needs, channel spacing has to be kept minimum so that more number of channels can be accommodated. Another approach is unequal channel spacing.it has been proposed and worked quite well for most cases since it avoids FWM product to fall on to any channels [10, 11].

In this paper we have designed 3-channel WDM systems and simulated the effect of FWM by varying chromatic dispersion parameter for equal and unequal channel spacing. The chromatic dispersion parameter is varied by varying the dispersion coefficient in different run of simulation.

IV SIMULATION SET UP AND DESCRIPTION

The simulation setup for a pump-probe configuration for NRZ modulator is shown in the figure.3. The simulation is carried out to observe the effect of FWM in WDM configuration in the presence of chromatic dispersion at 10 Gbps.

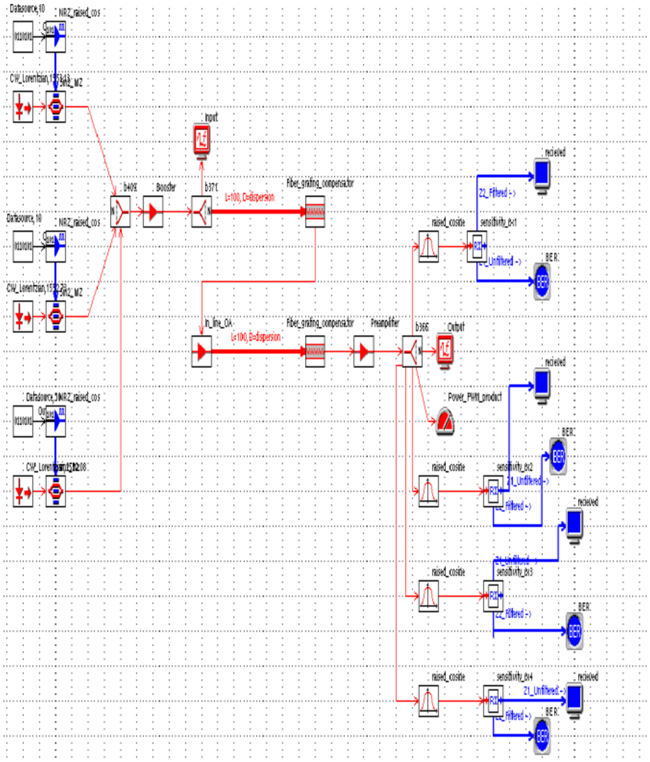


Fig.3. simulation set up for 3-channel WDM system.

A. *Transmitter section*

The transmitter consists of data source which generates pseudo random bit sequence at the rate of 10 Gbps. The bit sequence is fed to NRZ coder that produces an electrical NRZ coded signal. This signal is modulated using $\sin^2$ modulator. The modulator is driven by a CW_Lorentzian laser. Three channels are used in this simulation.

B. *Fiber section*

The three channels are multiplexed and the combined signal is fed into a fiber which is a single mode fiber. The nonlinearities are taken into account in this fiber. Using the optsim software we can induce different nonlinearities (FWM in this case). Also, different parameters like fiber length, attenuation, dispersion parameters can be adjusted. At the output of the fiber, the signal distorted with FWM is fed to a preamplifier prior sending to the receiver. Fiber is completely compensated at each span through ideal fiber gratings.

C. *Receiver section*

The output signal from the amplifier is demultiplexed and individual signals are received at the receiver. For each signal, there is an electrical low pass Bessel filter followed by the avalanche photodiode. It is having a cut off frequency of 193.175THz. at the output of the low pass filter, a scope is provided which is an electrical scope to display the eye diagrams, BER etc. A wide eye opening shows the minimum distortion.

V RESULTS and DISCUSSION

The simulation setup described above have investigated the effect of changing dispersion coefficient on FWM in WDM optical transmission system in terms of eye diagrams, input/ output spectrums, input pump power and probe power etc.

The channels are modulated at 10 Gbits/s data rate using NRZ format. The distance between the in-line optical EDFA fiber amplifiers is 100 Km (span length). The fiber dispersion value is varied from 0-4ps/nm-Km through parametric runs. The three signals are launched at 193.025 THz, 193.1 THz and 193.175 THz respectively, so that they have 75GHz uniform spacing. Table.1 shows the simulation parameters used in the set up.

Table.1.SIMULATION PARAMETERS

PARAMETER(unit)	VALUES
Pump frequency(THz)	193.025-193.175
Channel separation (GHz)	75
Probe frequency(THz)	193.1
Bit rate(Gbit/s)	10
Attenuation (db/Km)	0.2
Fiber length(Km)	100
Dispersion coefficient(ps/nm-Km)	0-4
Booster amplifier gain(dBm)	6
Preamplifier gain(dB)	25

The optical spectrum for input signals shown in Fig.4. The output spectrum of the signals for D= 0 ps/nm-km and D=4 ps/nm-km are shown in Fig.5 and Fig.6 respectively.

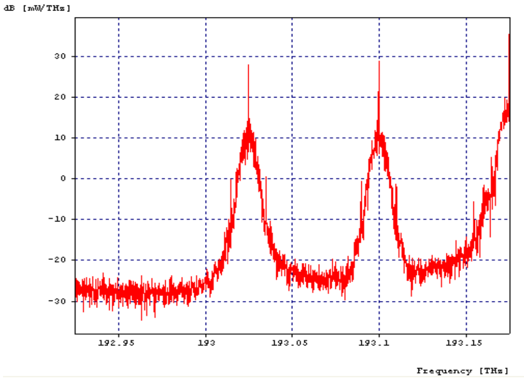


Fig.4. Input spectrum of 3-channels with equal channel spacing

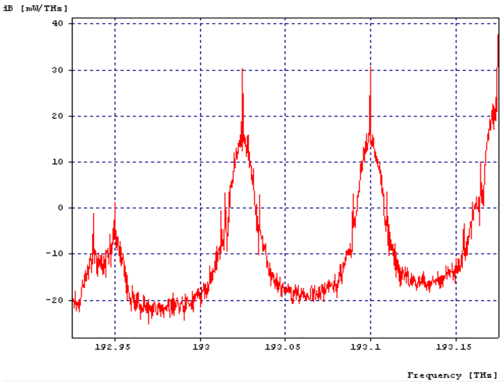


Fig.5.Output spectrum of 3-channel with equal channel spacing (when dispersion coefficient D=0)

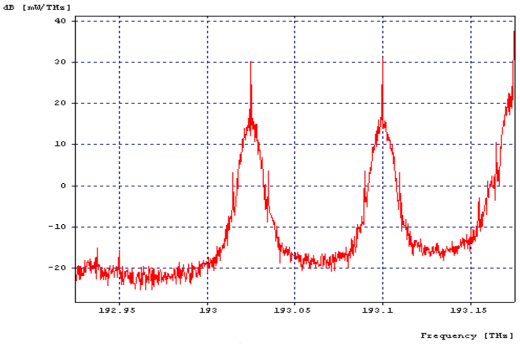


Fig.6.Output spectrum of 3-channels with equal channel spacing (when dispersion coefficient, D=4)

The output signal spectrums show that with the increase of dispersion the peak of the FWM effect in the spectrum is suppressed. At zero dispersion co-efficient the effect becomes significant and it generates other wavelengths of significant amplitude which are taking power from its parent signal. On the other hand, at Fig. 6 at dispersion co-efficient of 4ps/nm-km generated other wavelengths amplitude significantly small.

The performance of the probe channel (which is 193.1 THz) is also monitored at the receiver end by observing the eye diagram formation for equal as well as unequal channel spacing by varying the dispersion parameter. Fig.7 and Fig.8 show the effect of zero dispersion for equal and unequal channel spacing respectively.

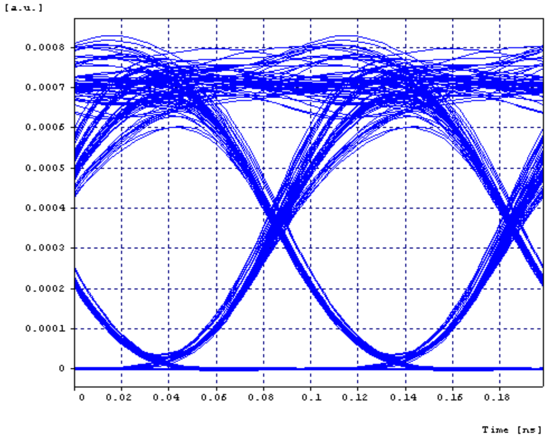


Fig.7. Eye diagram for equal channel spacing (when dispersion coefficient, D=0

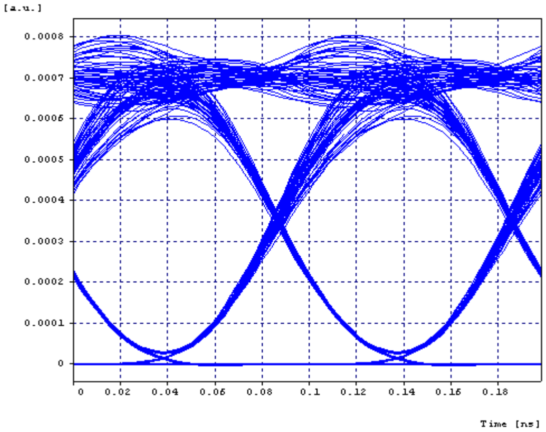


Fig.8. Eye diagram for unequal channel spacing (when dispersion coefficient, D=0)

In the above eye diagrams, the four wave mixing effect in case of unequal channel spacing has been slightly reduced and thus we can say that the performance of a WDM system is better with unequal channel spacing.

However the reduction is more significant even with equal channel spacing when dispersion coefficient is increased. This is shown in fig.9.

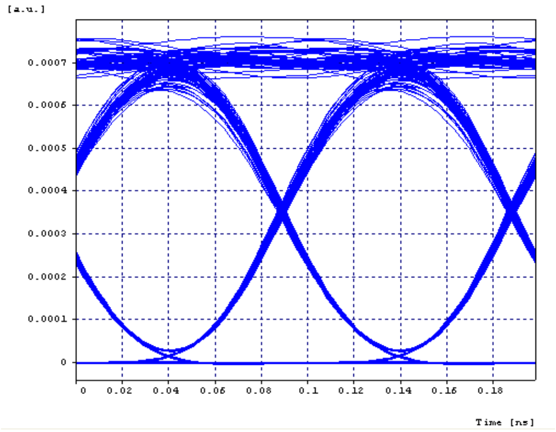


Fig.9. Eye diagram for equal channel spacing (when dispersion coefficient, D=4)

VI CONCLUSION

The impact of dispersion coefficient on FWM in a 3-channel WDM system has been demonstrated in this paper. The effect has been shown for both equal and unequal channel spacing. Results show that FWM is maximum when dispersion coefficient is minimum and reduces as the dispersion coefficient is increased. Also the performance of the system is found to be better with unequal channel spacing. Therefore in a WDM system in order to improve performance, unequal channel spacing is recommended with an optimized level of chromatic dispersion.

REFERENCES

[1] O. Aso , M. Tadakuma, and S. Namiki, “Four-wave mixing in optical fibers and its applications”, *Furukawa Review*, no. 19, pp. 63.68, 2000.

[2] P. L. Li, D. X. Huang, X. L. Zhang, J. Chen, and L. R. Huang,” Theoretical Analysis of Tunable Wavelength Conversion Based on FWM in a Semiconductor Fiber Ring Laser,” *IEEE Journal of quantum electronics*, vol. 41, no. 3, pp. 581-588, March 2005.

[3] G.charlet, E.corbel, J.Lazaro, A.klekamp, W.Idler, R.Dischler, S.Bigo “comparision ofsystem performance at 50,62.5 and 100 GHz channel spacing over transoceanic distances at 40Gcit/s channel rate using RZ-DPSK” *Electronics Letters 3rd*, vol.41, no.3, February 2005.

[4] Osamu Aso, Masateru Tadakuma and Shu Namiki,” Four-Wave Mixing in Optical Fibers and Its Applications”, *WP Team, Opto-technology Lab., R & D Div.*

[5] G. P. Agrawal, "Nonlinear Fiber Optics, Second Edition", *Academic Press, San Diego, USA*, Chap. 10, 1995.

[6] Yamamoto, Optical Fiber Communications Technology, Nikkan Kogyo Shimbun, Chap.11, 1995.

[7] Edmund Kueh Boon Kiang, S. P. Majumder, “Analytical Evaluation of the Impact of Four Wave Mixing on the Bit Error Rate Performance of a WDM Soliton Transmission Link”, *Journal of Optical Communications*, vol. 23, no. 4, pp. 122-126, 2002.

[8] J. Zweck and C. R. Menyuk, “Reduction of intra-channel four-wave mixing using subchannel multiplexing”, *IEEE Photonics TechnologyLetters*, vol. 15, no. 2, pp. 323-325, 2002.

[9] M. Kowalewski, M. Marciniak and A. Sedlin, "Nonlinear interactions in wavelength-multiplexed optical fibre telecommunication systems", *J. Opt. A: Pure Appl*. Opt. 2 pp.319–326. 2000.

[10] S. Shuxian, "Higher-order four-wave mixing and its effect in WDM systems," *Optical Society of America*, vol. 7, no. 4, pp 166-171, 2000.

[11] H. G. Batshon, I. B. Djordjevic, and B. V. Vasic, "An improved technique for suppression of intrachannel four-wave mixing in 40-Gb/s optical transmission systems", *IEEE Photonics Technology Letters*, vol. 19, no. 2, pp. 67-72, 2007