ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

Study of Four Wave Mixing Effect on Wavelength Division Multiplexing Optical Fiber Communication System

Mohit Tyagi[1], Amit chaudhary[2]

M.Tech Scholar, Dept. of ECE, Subharti University, Meerut, U.P, India[1]

Assistant Professor, Dept. of ECE, Subharti University, Meerut, U.P, India[2]

ABSTRACT: In Optical fiber communication the nonlinear effects degrade the system performance. Nonlinear effects tend to manifest themselves when optical power is very high; they become important in Dense Wavelength Digital Multiplexing (DWDM). Four-wave mixing (FWM) is one of the dominating/leading degradation effects in wavelength division-multiplexing (WDM) systems with dense channel spacing and low chromatic dispersion on the fiber [1]-[6]. If in a WDM system the channels are equally spaced, the new waves generated by FWM will fall at channel frequencies and, thus, will give rise to crosstalk [2]-[8]. Four-wave mixing (FWM) is a parametric process in which different frequencies interact and further generate new spectral component. Linear effects such as attenuation and dispersion can be compensated, but nonlinear effects accumulate. They are the fundamental limiting mechanisms to the amount of data that can be transmitted in optical fiber communication. In this paperthe four wave mixing effect has been compared for different values of ultra-low channel spacing and the performance has been evaluated in terms of output spectrums, eye diagrams, bit error rate, eye opening and Q-factor[7]-[9]-[10]. Here, all the channels are spaced evenly but at different values like 6.25 GHz, 10 GHz, and 20 GHz etc. The simulation results reveal that four wave mixing is minimum at high wavelength spacing's.

KEYWORDS: Wave length division multiplexing (WDM), Dense Wavelength Digital Multiplexing (DWDM), and Bit error rate (BER), Quality-factor (Q-F), Stimulated Raman Scattering (SRS), Stimulated Brillouin Scattering (SBS), Bit Error Rate (BER), and Optical Spectrum Analyzer (OSA).

I. INTRODUCTION

This article provides concepts of Four Wave Mixing which is a type of Nonlinearity. Due to the widespread growth in wireless communication, network operators are facing difficulty in accommodating the growing traffic.WDM appears to be a viable solution to such problems posed by the micro cellular system [1].WDM system however suffers from nonlinear effect in fibbers [2]. Communications in WDM generate new waves under appropriate condition through a variety of Non-linear phenomena such as Stimulated Raman Scattering (SRS), Stimulated Brillouin Scattering (SBS), Self-Phase Modulation (SPM), and Four Wave Mixing (FWM).

A.Four-wave mixing (FWM)

Four-wave mixing (FWM) (also called four-photon mixing) is one of the major limiting factors in WDM optical fiber communication systems that use the low dispersion fiber or narrow channel spacing. Normally, multiple optical channels passing through the same fiber interact with each other very weakly. The most important is FWM in which three wavelengths interact to generate a fourth. FWM is due to changes in the refractive index with optical power called optical Kerr effect. When three electro-magnetic waves with optical frequencies co- propagate through one fiber, they mix to produce a fourth intermodulation product. In the FWM effect, three co- propagating waves produce nine new optical sideband waves at different frequencies [6]-[7]. When this new frequency falls in the transmission window of the original frequencies, it causes severe cross talk between the channels propagating through an optical fiber. FWM occurs when light of three different wavelengths is launched into a fiber; it gives rise to a new wave [3]. This newly generated wave as a result of FWM co-propagates with the originally transmitted signal and interferes with them. It

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

causes severe degradation for the WDM channels and introduces the crosstalk and required power to reduce the crosstalk. When a high-power optical signal is launched into a fiber, the linearity of the optical response is lost. One such nonlinear effect, which is due to the third-order electric susceptibility, is called the optical Kerr effect. 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 [9]. The light present before launching, sandwiching the two pumping waves in the frequency domain, is called the probe light (or signal light).

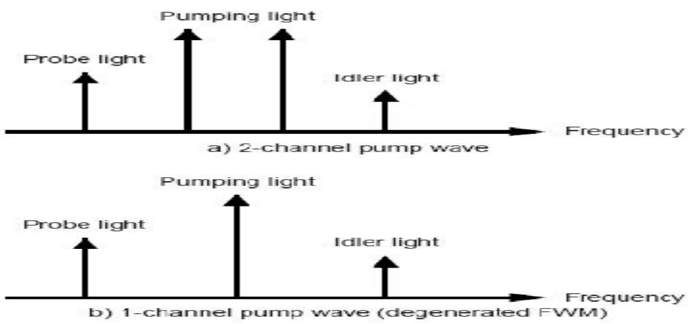


Figure 1: *Schematic of four wave mixing in frequency domain*

II. SCHEMATIC MODEL

The schematic model for an optical communication system implementing the four wave mixing effect for various values of spacing between different users is presented in Figure 2. N input channels/users are taken in this case for reference [4]. The number of users can vary depending on various constraints like the bandwidth range.

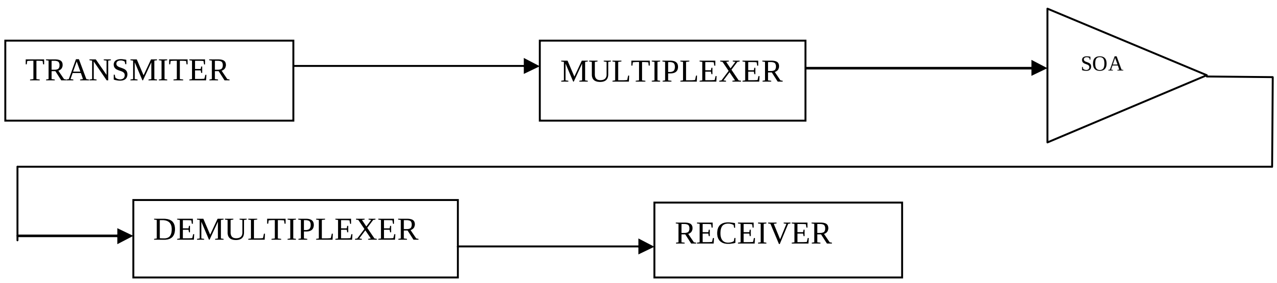


Fig 2: *Schematic Model*

This schematic model is the general setup for an optical communication system in which nonlinear fiber is installed which adds non linearities like four wave mixing. The post-amplifier, in line amplifier and pre-amplifier are used in case of long transmission distances. The transmitter section consists of a laser, modulator driver, pn-sequence generator i.e. data source and modulator. The wavelength of various channels is set by keeping the difference equal to the spacing required. Then all these transmitted signals are combined/multiplexed together. Then the combined signal is amplified so that it can be transmitted over long distances without its degradation. Then the signal is transmitted over the non linear fiber which adds the nonlinearities into the signal [5]. At the receiver side, the signal is demultiplexed. The receiver consists of a photodiode and a low pass filter.

III.SIMULATION SETUP

The simulation setup for showing the effect of changing spacing between the input channels on four wave mixing is shown in Figure 3.The continuous wave laser (L_1-L_8) is used to generate the carrier signal. In this setup, eight users are taken in account whose wavelengths have a specific difference i.e. spacing between them. The frequency of first user is

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

kept at 192.98 THz. The wavelength of next users is set as per the spacing requirement i.e. at wavelength difference of 6.25 GHz, 10 GHz, 20 GHz, 25 GHz, and 75 GHz. The data source (ds_1-ds_8) is used to generate the random input data bit sequence at the rate of 10 Gbps. The light signal modulates the input data. The modulator (m_1-m_8) is driven by the modulator driver (d_1-d_8) which decides the input data format. The input data format used here is NRZ raised cosine. The modulated data from all the users is combined using a combiner (c_1).The post amplifier (a_1) amplifies the signal before Transmitter 1-N Multiplexer SOA allowing it to enter into the fiber to avoid losses .Then this signal is sent over the fiber (f_1) of length 100 Km. All the attenuation, dispersion and non linear effects are activated. The in-line amplifier (a_2) amplifies the signal in the transmission medium itself. Then the signal is again passed through a fiber (f_2) of length 100 Km. Then pre-amplifier (a_3) is used to amplify the signal before allowing it to enter into the receiver section.
After amplification, the signal reaches the receiver. At the receiver, the signal is demultiplexed by using a splitter (s_1) which splits this signal into the same number of signals as were transmitted. The photodiode (p_1) is used for optical to electrical conversion. Then the signal is passed through the Bessel filter (Lf_1) which is made to work as low pass filters and the final output signal is received. An optical scope ($probe_1$) is attached at the output of combiner to examine the input signal. Another optical scope ($probe_2$) is placed at the output of splitter to examine the four wave mixing effect in frequency spectrum. An electrical scope ($scope_{32}$) is kept at the receiver output to examine the eye diagram, Bit Error Rate, Q-factor. Some optical scopes are placed in the intermediate stages to analyze the output.

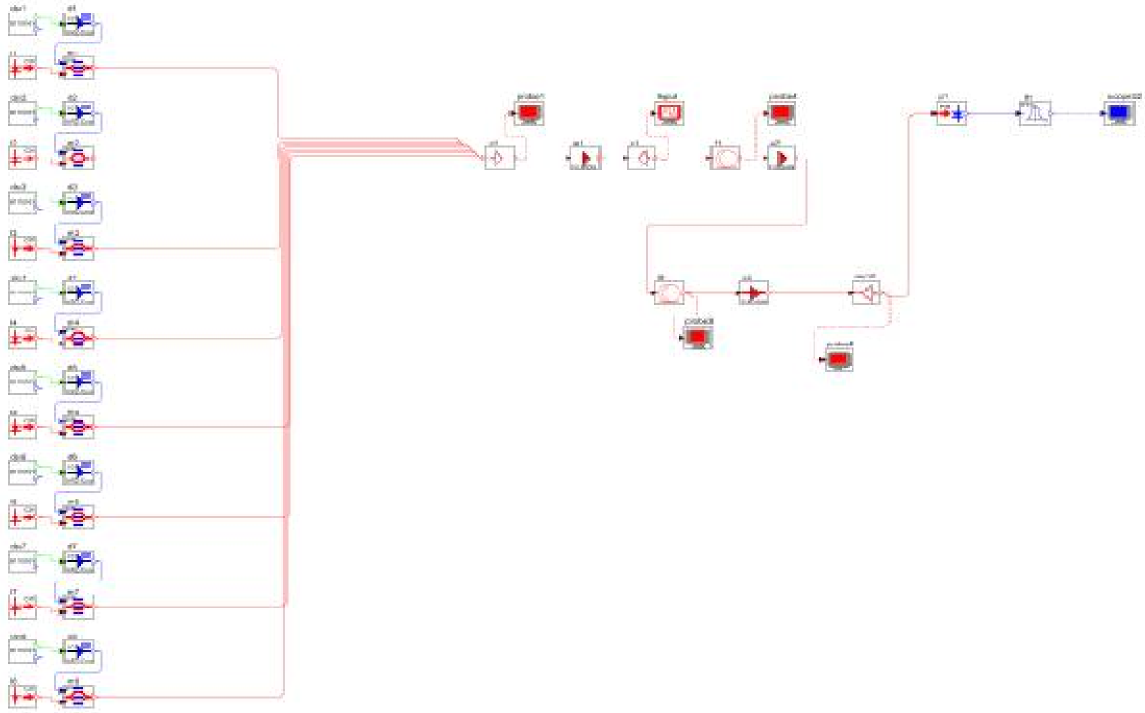


Figure 3: *Simulation setup*

IV.SIMULATION RESULT

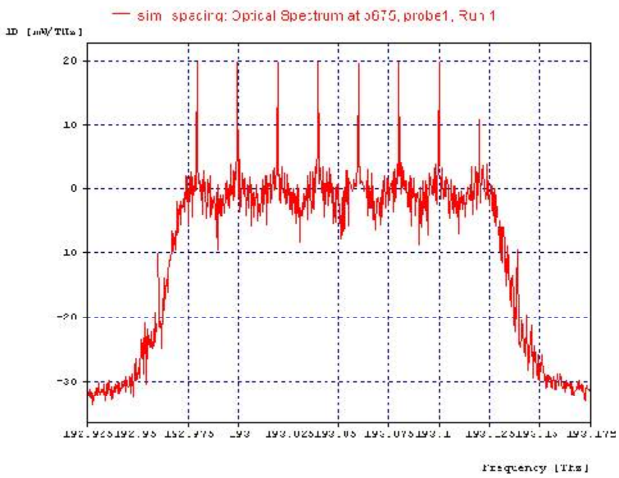


Figure 4: *Input optical spectrum used for analyzing FWM effect*

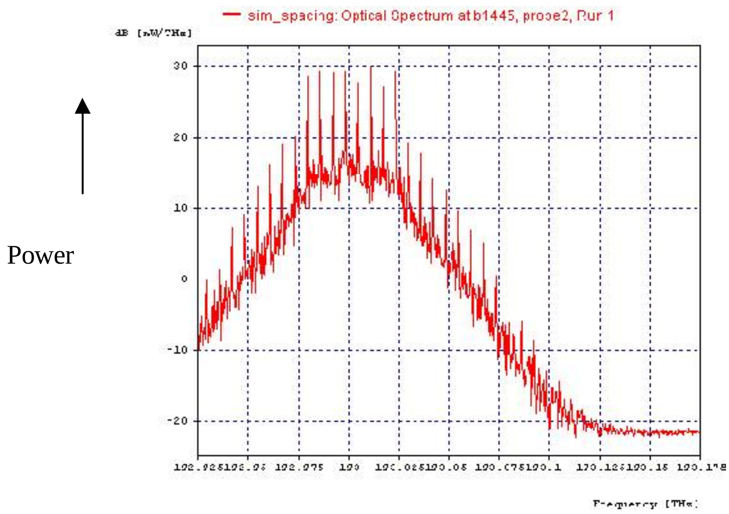


Figure 5: *Output spectrum for 6.25 GHz spacing*

The four wave mixing effect is clearly seen in the above output spectrum for 6.25 GHz spacing as unnecessary peaks at various frequencies are occurring at the sides of the input spectrum. Moreover, the peaks at the input frequencies have also diminished due to four wave mixing occurred after crossing the non linear fiber.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

Power

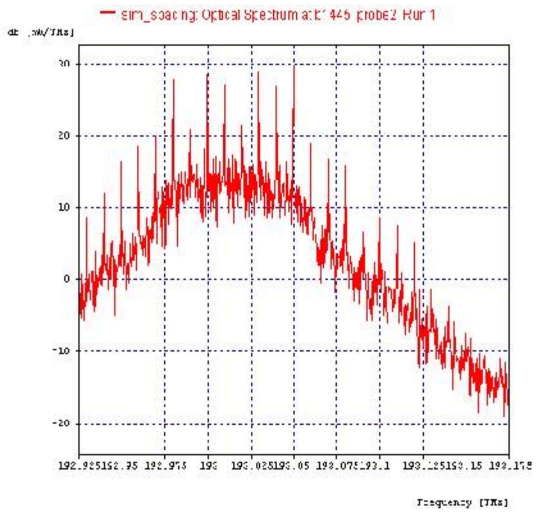


Figure 6*:* *Output spectrum for 10 GHz spacing*

Power

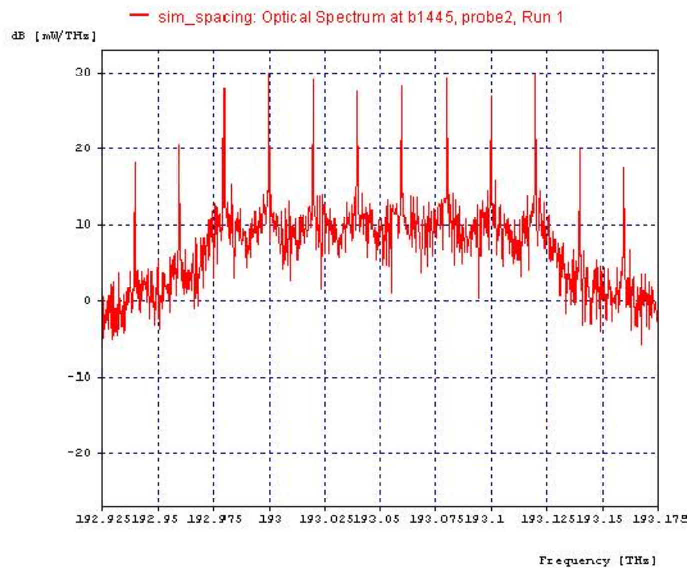


Figure 7: *Output spectrum for 20 GHz spacing*

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

Power

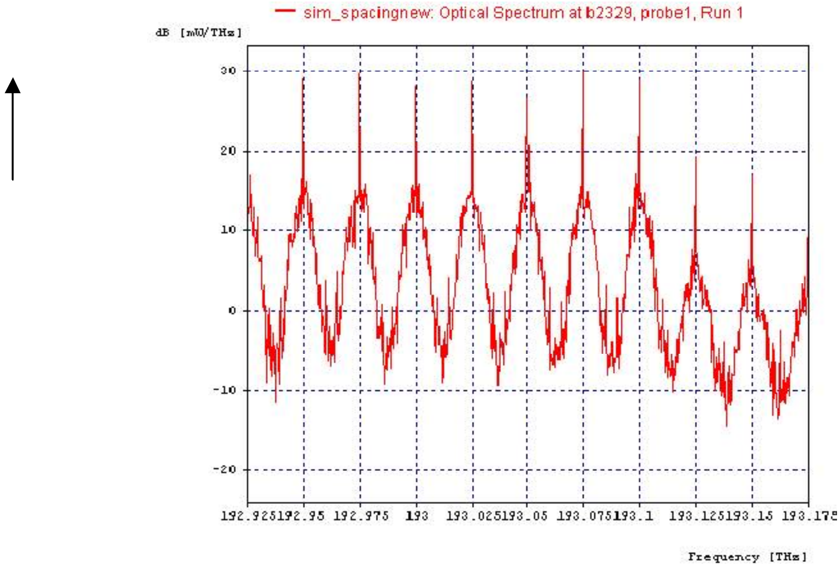


Figure 8: *Output spectrum for 25 GHz spacing*

Power

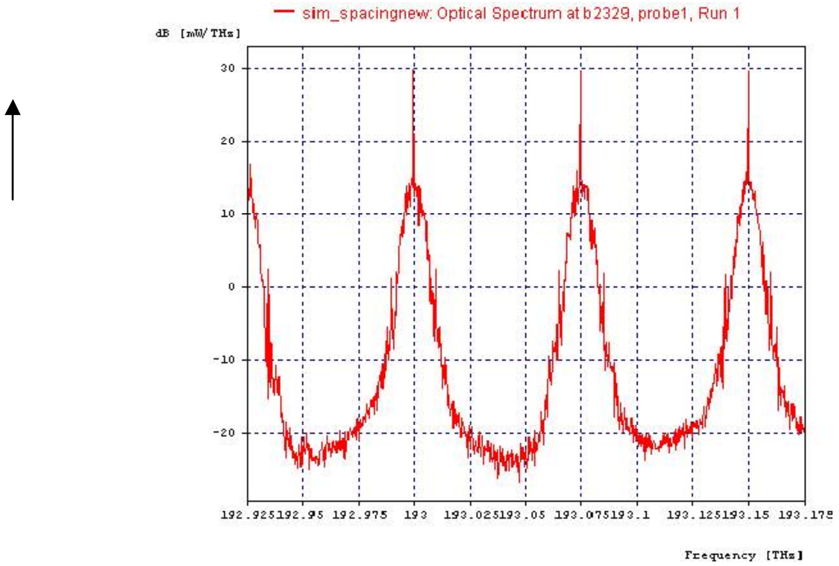


Figure 9: *Output spectrum for 75 GHz spacing*

The above spectrums shows that as the spacing between the input channels/users increases, the four wave mixing effect goes on decreasing. The unwanted peaks are maximum when the spacing is 6.25 GHz and are minimum when the spacing is 75 GHz. This shows that lesser the spacing between different input users/channels, more is the interference between the input frequencies i.e. more is the four wave mixing effect. On increasing the spacing between the input channels, the four wave mixing decreases. Figure 10(a) shows the variation of bit error rate on the basis of spacing between the input channels. The figure shows that bit error rate goes on decreasing with the increasing spacing.

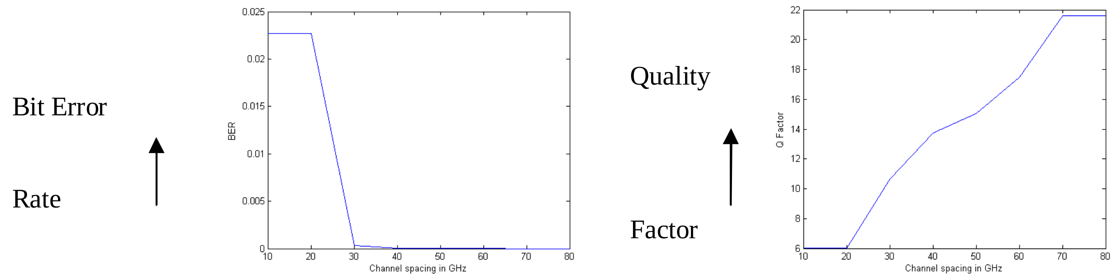
ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017



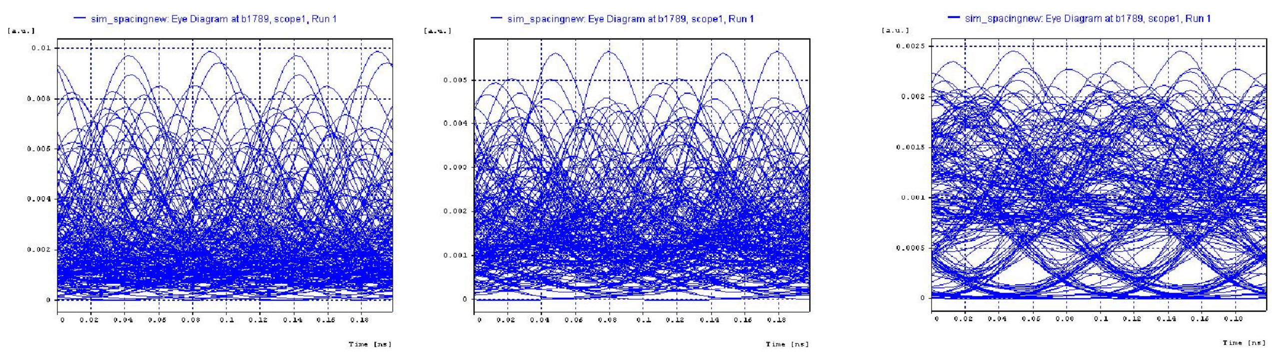
(a) (b)

Figure 10: *Variation of BER (a) and Q-factor (b) with respect to Channel spacing*

Figure 10(b) shows the variation of Q-factor with the spacing between the input channels. The graph shows that the Q-factor increases on increasing the channel spacing. It is maximum when the channel spacing is 80 GHz and is minimum when the channel spacing is 6.25 GHz.

Figure 11 shows the eye diagrams for the various values of channel spacing. Figure 11 (a) shows the eye diagram for 6.25 GHz spacing. Figure 11(b) shows the eye diagram for 10 GHz spacing. Figure 11 (c) shows the eye diagram for 20 GHz spacing. Figure 12(d) shows the eye diagram for 75 GHz spacing.

The below eye diagram shows that there is large interference between the input frequencies. The bit error rate is quite large at 6.25 GHz. Thus, four wave mixing is quite large when the spacing between the input channels is 6.25 GHz.



(a) ***(b)*** ***(c)***

Figure 11*: Eye diagram for 6.25GHz (a), 10 GHz (b), 20 GHz(c) spacing*

The above eye diagrams show that the eye diagram clarity goes on increasing with the increasing spacing between the input channels. This shows that the interference between the input frequencies and hence the four wave mixing effect decreases with the increasing channel spacing.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

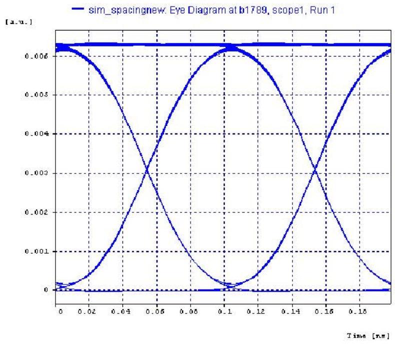


Figure 12: *Eye diagram for 75 GHz spacing*

V.CONCLUSION

In this chapter, the design, implementation and performance analysis of four wave mixing in optical communication system for different values of spacing between input channels is presented. The comparison of four wave mixing effect at various values of channel spacing revealed that 75 GHz spacing has the edge over 6.25 GHz spacing in optical communication system. It is found that spacing of 75 GHz has the lowest bit error rate and better system performance as we can see for the spacing of 75 GHz eye opening is maximum. Hence, the higher spacing values between the input channels are recommended for long distance transmission without four wave mixing. It can be seen from the graphs of bit error rate, Q-factor and eye opening that higher channel spacing gives the best performance as compared to lower channel spacing. Hence, it is concluded that higher channel spacing is best suitable to be employed in the optical communication systems minimizing the four wave mixing effect.

VI. FUTURE SCOPE

In this Paper, the work is limited to four wave mixing effect. The variation of bit error rate, Q-factor, eye opening and output spectrums with four wave mixing on changing various parameters like channel spacing, number of channels, various components like modulators, drivers etc have been considered. The effect of changing these parameters for self phase modulation, cross phase modulation i.e. other Kerr effects can be studied. Four wave mixing can be used for various applications like wavelength conversion. So, various applications of four wave mixing can be further studied. Also, different other methods of reducing the four wave mixing effect can be explored.

REFERENCES

[1]. Naresh Kumar, Ajay K. Sharma, VinodKapoor, “XPMInduced Crosstalk with Variety of Fiber in SCM-WDM Optical Transmission Link”, pp.
[2].Govind P. Agrawal, “Fiber-Optic Communication System”, 3rd ed., Wiley, New York, 2002.
[3].Govind P. Agrawal, “Nonlinear Fiber Optics”, Third Edition.
[4]. A.J. Mendez, R.M. Gagliardi, V.J. Hernandez, C.V. Bennett, and W. J. Lennon, “Design and Performance Analysis of Wavelength/Time (W/T) Matrix Codes for Optical CDMA,” IEEE Journal of Lightwave Technology, vol. 21, pp. 2524-2533, November 2003.
[5]. Gerd Keiser, “Optical Fiber Communications, Fourth Edition” McGraw Hill, 2008.
[6]. Osamu Aso, MasateruTadakuma and ShuNamiki,” Four-Wave Mixing in Optical Fibers and Its Applications”, WP Team, Opto-technology Lab., R & D Div, October 1999IEEE Photonic Technology Letters, Vol. 17, No. 1 January 2005.
[7].JianHui Zhou, Namkyoo, “Four Wave Mixing Wavelength Conversion Efficiency in semiconductor Travelling wave Amplifiers Measured to 65nm of Wavelength shift”, IEEE Photonics Technology Letter, Vol. 6, No. 8, August 1994.
[8].T. Sabapathi, S. Sundaravadivelu,"Analysis of Bottlenecks in DWDM Fiber Optic Communication System", Optik 122, pp. 1453– 1457, 2011.
[9].Rajneesh Kaler, R.S. Kaler, “Investigation of four wave mixing effect at different channel spacing”, sciencedirect journal, Optiks.
[10].S. P. Singhand N. Singh, “Nonlinear Effects In Optical Fibers: Origin, Managementand Applications” Progress In Electromagnetics Research, PIER 73, 249–275, 2007.
[11].G. P. Agrawal, "Nonlinear Fiber Optics, Second Edition", Academic Press, San Diego, USA, Chap. 10, 1995.
[12]. G.P. Agarwal, Fiber Optic Communication Systems, Wiley, New York, 1997.