Analysis of Wave Length Conversion using Four Wave Mixing Effect in an Optical Fiber

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***Abstract*- Optical communication is process of transmitting information signal from source to destination in the form of light pulses. The main advantage of using optical fiber communication system is its large bandwidth, low error rate and high capacity. The high capacity in fiber optic communication system is further increased by using wavelength division multiplexing (WDM) transmission in optical transmission system. But when a high power optical signal passes through an optical fiber it gives rise to many non linear effects such as four wave mixing (FWM) which degrades the overall performance of optical fiber transmission system. But the phenomenon of four wave mixing can be used as a wavelength converter to convert the wavelength of an information carrying signal to another wavelength. In this paper investigation has been done on four wave mixing based wavelength conversion at 10 Gbps data rate over a 100 km long optical fiber link. It can be seen from the results that as power of transmitted information signal is increased the power of converted signal increases.**

Keywords- Wave Division Multiplexing (WDM); Non Linear Effects; Four Wave Mixing (FWM); Wavelength Conversion

I. INTRODUCTION

The refractive index of an optical fiber depends on the power of the optical signal which passes through the fiber. This induces a non linear effect in the fiber, which results in change in properties of the fiber in accordance to the power of optical signal which passes through the fiber [1], [3]. Four wave mixing (FWM) is a kind of non linear effect which occurs when two or more optical signal with very high powers passes through the optical fiber. These high powered optical signals which passes through the optical fiber, results in production of two or more optical signals known as beat frequency signals, which lie within the frequency range of the original signals that carry information [2]. Normally the four wave mixing (FWM) effect is avoided, but it can be used for different applications. The phenomenon of four wave mixing can be used to transmit the information at a new wavelength, which is produced as a result of interaction between two or more waves passing through the fiber at high power [5]. The effect of four wave mixing is more prominent if channel spacing between the signals passing through the optical fiber is equal and the power of transmission of optical signal carrying information is high. Investigation conducted by R.S Kaler et al. [1] presented that as the spacing between the channels is increased and kept unequal, the amount of interference between the signals carrying information is reduced and thus the efficiency of four wave mixing effect is reduced. S. JD. Marconi et al. [2] presented an efficient technique of generation of frequency comb having spacing between the channels of the order of hundreds of GHz by use of three pump technique. K S. Chiang et al. [3] demonstrated the possibility of generation of a distinct frequency-shifted beam by using a distinct optical pump beam and mixing it with information signal. Bobby Barua et al. [4] proposed the use of an optical fiber having low chromatic dispersion coefficient which results in higher efficiency of four wave mixing (FWM) effect. In order to increase the transmission distance of information carrying signal an optical amplifier is used. As the transmitting power of the information carrying signal is increased, the power of beat frequencies produced as a result of FWM effect is also increased. The main objective of this paper is to study the effect of four wave mixing in optical fiber and to present the four wave mixing based wavelength conversion in optical fiber.

The rest of the paper is organized as follows: in section 2, the four wave mixing (FWM) effect is discussed briefly. In section 3, the simulation setup and the different simulation parameters are presented. In section 4, results and discussions are presented and in section 5 the conclusion of the paper is discussed.

II. FOUR WAVE MIXING (FWM) EFFECT

Four Wave Mixing (FWM) is a non linear effect that occurs in case of wavelength division multiplexing (WDM) systems where channels are very closely spaced to each other. This effect is generated as a result of third order distortion that results in third order harmonics [4]. The mix products produced as a result of four wave mixing effect interfere with the original signal as shown in Figure No.1. As a matter of fact, these mix signals lie within the frequency interval between the original information carrying signal which causes difficultly to filter them out.

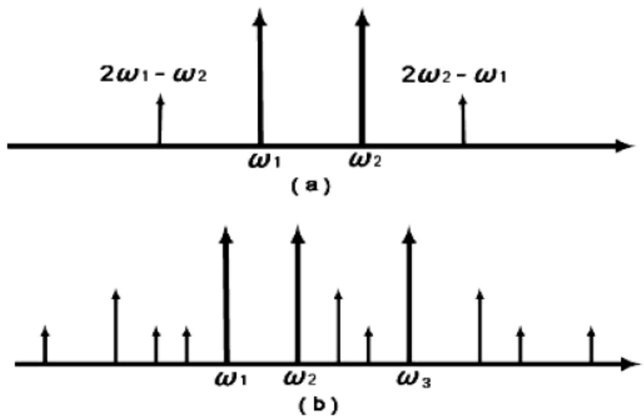

Figure No.1: (a) Two input signals at frequencies ω_1 *and* ω_2. (b) Three input signals ω_1, ω_2 and ω_3 and the new frequency components due to FWM effect [6]

The number of mix frequencies generated as a result of four wave mixing effect is given by [7]:

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

Where N denotes the number of channels available and M denotes the numbers of mix frequencies generated.

III. SIMULATION SETUP

In this investigative study, Optisystem 7.0 simulation software has been used to carry out different simulations and to analyze the four wave mixing (FWM) based wavelength conversion in optical fiber. Table No.1 shows the different simulation parameters used in the analysis.

Table No.1

Serial No.	Parameter	Value
1.	Bit rate	10 Gbps
2.	Reference Wavelength	1550 nm
3.	Length of optical fiber	8 Km
4.	Dispersion Coefficient	-75 ps/nm/km
5.	Dispersion slope	-0.001 ps/nm^2/km
6.	Differential Group Delay	0.5 ps/km
7.	Effective Area	80 um^2
8.	Attenuation	0.2 dB
9.	Filter Type	Gaussian
10.	Bandwidth	20 GHz
11.	Order	3
12.	Extinction Ratio	30 dB
13.	Source Laser Frequency	193.1 THz
14.	Pump Laser Frequency	193.2 THz
15.	Transmission Power	12 dB

Figure No. 2 represents the simulation model used in this analysis and figure no. 3 represents the Optisystem simulation setup used in this analytical work.

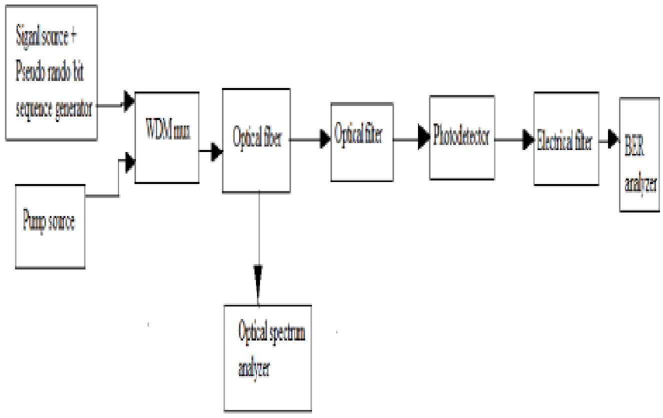

Figure No. 2 Simulation Model

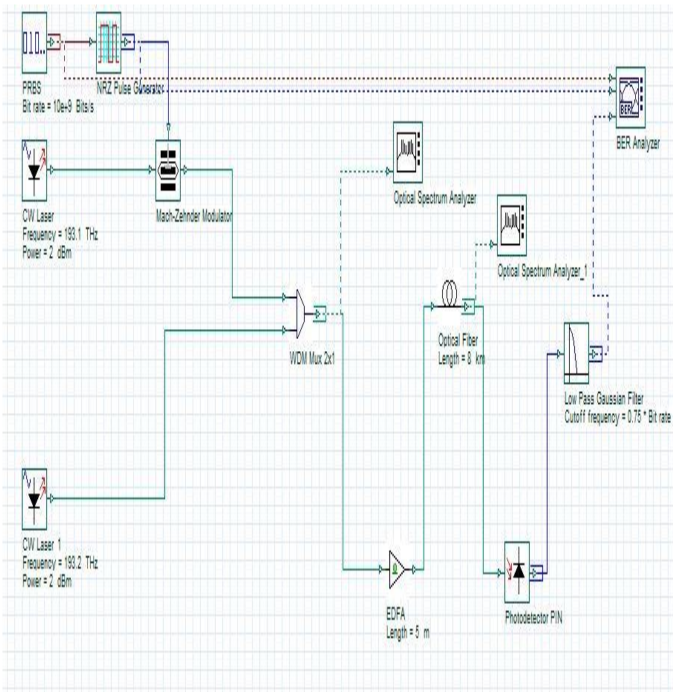

Figure No. 3 Simulation Setup

As shown in figure no. 3 the simulation setup consists of a transmitter section, a receiver section and a transmission path. The transmitter section consists of a pseudo random pulse generator which generates random binary signal in form of 0's and 1's at 10 Gbps data rate, which are directed towards a NRZ pulse generator which converts the binary signal to an electrical signal having NRZ format. This electrical signal is modulated by a Mach Zender modulator which has two inputs one from the NRZ pulse generator and other from the continuous wave laser having central frequency at 193.1 THz. This simulation setup uses another continuous wave laser as a pump laser having central frequency at 193.2 THz. Both the source laser and pump laser inputs are fed to a WDM mux. The output of this mux is directed towards a single mode fiber of length 8 km in which non linear effects results in production of new signals at different wavelength. The output of the optical fiber is directed towards a EDFA amplifier which amplifies the received signal and its output is directed towards a PIN photodiode which converts the optical signal into an electrical signal. The output from this photodiode is directed to a low pass Gaussian filter which removes any high frequency noise present in the received signal. The quality factor and the bit error rate of received signal is visualized using BER analyzer. Optical spectrum analyzer is used to investigate the frequency spectrum the signal at different stages.

IV RESULTS AND DISCUSSIONS

As shown in Figure No. 3 two information carrying optical signals having wavelengths 1550 nm and 1552 nm are applied at the input of the optical fiber. Due to the phenomenon of four wave mixing in optical fiber, new frequency signals are produced which are known as beat frequency signals and they travel along the original information carrying signal. An Erbium Doped Fiber Amplifier (EDFA) has been used to receive the signals properly. Figure No. 4 shows the spectrum of optical signals before entering the optical fiber and Figure No. 5 shows the spectrum of optical signal received at the end of optical fiber which contains mix frequency signals generated as a result of four wave mixing effect.

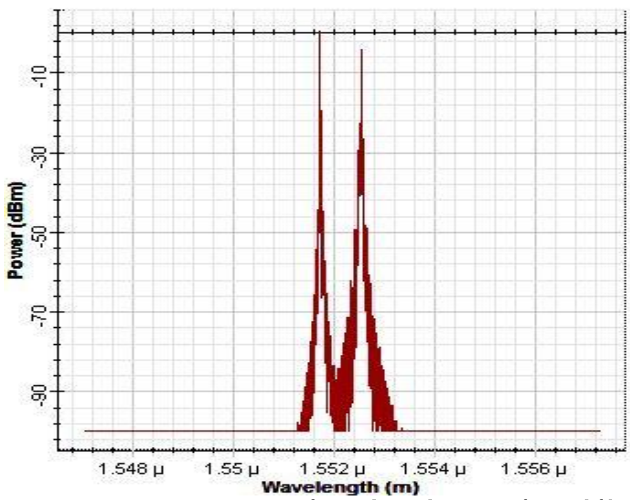

Figure No. 4 Frequency spectrum of optical signal at input of optical fiber

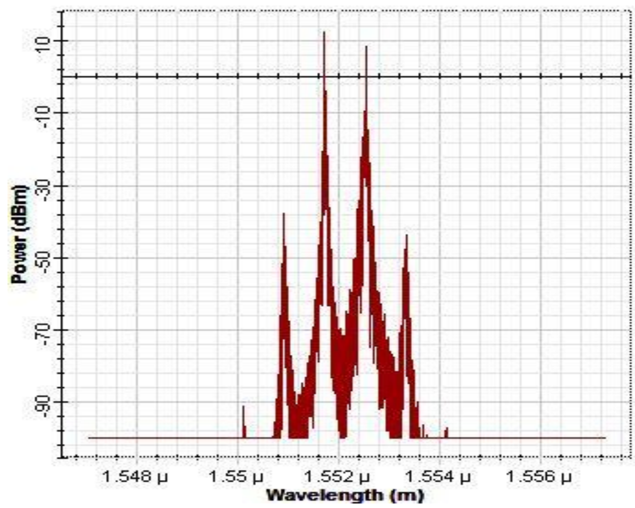

Figure No. 5 Frequency spectrum of optical signal at output of optical fiber

It is clear from Figure No.5 that as a result of four wave mixing (FWM) phenomenon in optical fiber new signal are produced at different frequencies which can be used to carry information. Figure No.6 shows graph between converted optical signal and input optical signal. It is clear from the graph that as the transmission power increases; the power of converted signal also increases.

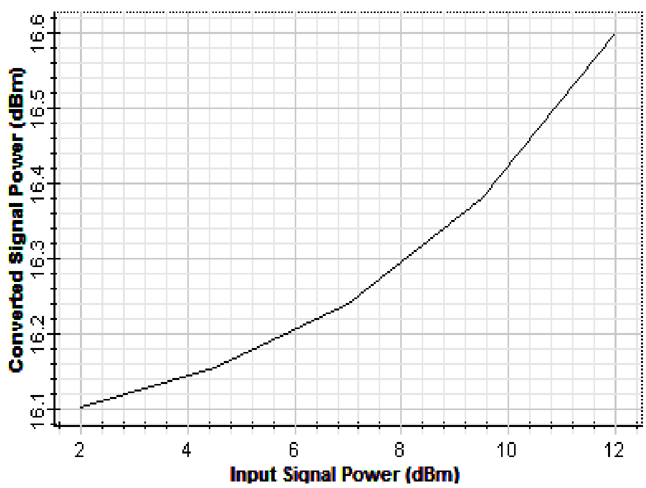

Figure No. 6 Converted signal power versus input signal power

Eye diagram of signal received at the output of the optical fiber is shown in Figure No.7.

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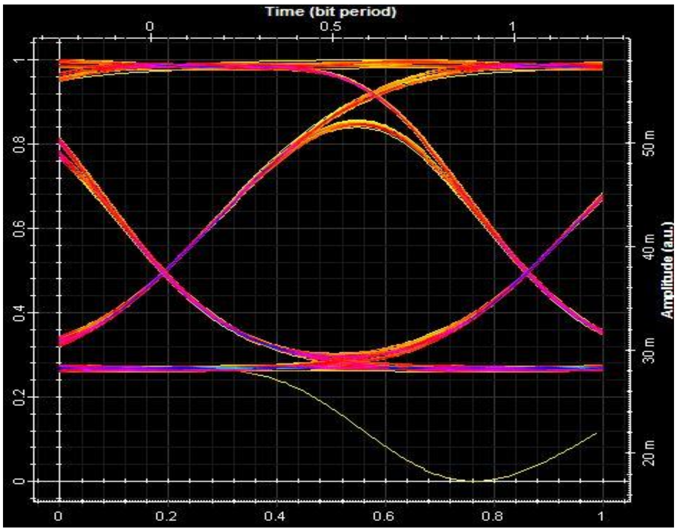

Figure No. 7 Eye Diagram of received signal at the output.

V. CONCLUSION

In this investigative study, it has been shown that how nonlinear affects in optical fiber such as Four Wave Mixing (FWM) effect can be used to convert wavelength. From the results presented above is concluded that as the transmitting power of the laser at transmitting end increases, the efficiency of four wave mixing effect increases and thus the power of converted signals also increases. This scheme of wavelength conversion by non linear effects in optical fibers can find many applications in optical packet routers.

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