PERFORMANCE ANALYSIS OF FWM AT VARYING DISPERSION VALUES AND BIT RATES

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Abstract: Long haul multichannel optical communication system is extremely affected by nonlinear effect like four wave mixing (FWM). The FWM effect depends on channel separation, number of channels and bit rates. This paper presents the design and performance analysis of FWM effect on bit error rate, Q-factor, eye opening, jitter etc. at variable bit rates and dispersion values.

Keywords: *FWM (Four Wave Mixing), dispersion, bit rates.*

1. INTRODUCTION

The rapid expansion of optical fiber communication systems and technologies can be credited, in part, to the deployment of wavelength division multiplexing systems, allowing multiple independent data channels per fiber. In addition, the use of longer amplifier span, more channels per fiber, higher signal power levels, reduces the costs, may allow further expansion. With the increase in transmission distance and number of channels, signals become more vulnerable to a number of debilitating fiber nonlinear effect [1-2]. To improve this, network operators routinely ensure that signal power levels remain below a “safe” threshold, where the degradation induced by the non-linearties is negligible. However as the trend of optical and networking technologies expand, some advancement has been made, like reconfigurable, dynamic optical network, where channels may be routed optically, and channels/wavelengths are added and dropped routinely at network nodes [3]. Since the output power of each channel of a saturated EDFA depends on the number of input channels, a frequently changing in the number of channels may results in large increase in nonlinear effects as the signal travels down the amplifier chain. The key nonlinear effects in such systems are self phase modulation, cross phase modulation and four wave mixing [4]. Kaler et al. showed that FWM effect can be suppressed by increasing dispersion in the fiber. The FWM signal power decreases with increasing dispersion but the decrease is not same for equal and unequal spacing. The decrease in FWM power is more for unequal spaced channels as compared to equal spaced channels. Further it showed that with increase in effective area of the fiber, the FWM effect has been reduced. The combined effects of effective area and dispersion are also investigated for FWM [5]. Manna et al. presented that Four Wave Mixing (FWM) resonances can affect performance of selected channels within the dense wavelength-division-multiplexing band. The FWM resonances may cause Q-factor penalty in excess of 1 dB. They developed an analytical model to predict the spectral location and the intensity of the resonances. Dispersion slope-matched maps and manufacturing variations help to suppress the resonances [6]. Nakajima et al. described about the Four Wave Mixing (FWM) suppression effect of dispersion varying fiber (DVF) whose chromatic dispersion increases (or decreases) along the length. The FWM suppression performance is investigated for the dispersion variation rate and its cycle number in the DVF [7]. Bang et al. described that CPM and FWM are significant nonlinear optical effects in DWDM systems. CPM leads to spectral broadening which may cause severe pulse distortion [8]. Melloni et al. showed that in ideal conditions the Four Wave Mixing conversion efficiency is enhanced by the slowing down factor to the

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fourth power. They have investigated FWM in Coupled Resonator Optical Waveguides both numerically and experimentally this phenomena, also in presence of attenuation and chromatic dispersion [9].

2. FOUR-WAVE MIXING

Four-wave mixing (FWM), a type of optical Kerr effect that occurs when light of two or more different wavelengths is launched into a fiber. Fig. 1 explains the phenomenon of four-wave mixing in the frequency domain. As can be seen, the light that was there from before launching, sandwiching the two pumping waves in the frequency domain, is called the probe light. The idler frequency f_{idler} may then be determined by

$$f_{idler} = f_{p_1} + f_{p_2} - f_{probe} \quad (1)$$

Where, f_{p_1} and f_{p_2} are the pumping light frequencies, and f_{probe} is the frequency of the probe light [10].

Fig. 1: Two channel pump wave

FWM can deteriorate the system performance in optical fiber communications, particularly in wavelength division multiplexing where it can cause cross-talk between different wavelength channels [11].

3. SYSTEM DESIGN AND ANALYSIS USING DIFFERENT BIT RATES

System layout (as shown in Fig. 2) is divided in three sections viz. transmitter, channel and receiver. In the transmitter section, source signal is sent to optical modulator along with light wave from laser source. Input optical signal is observed with the help of optical analyzer. In second section, two WDM channels are launched over two DS fiber spans of 100 km, each. Dispersion is completely compensated at each span. Optical amplifiers are used to amplify the weak signal. In the receiver block, a filter is used in FWM receiver to attenuate the received signal to limited frequencies, and then the signal is sent to the photodetector. The optical signal can be seen at the output of optical splitter at the receiver side.

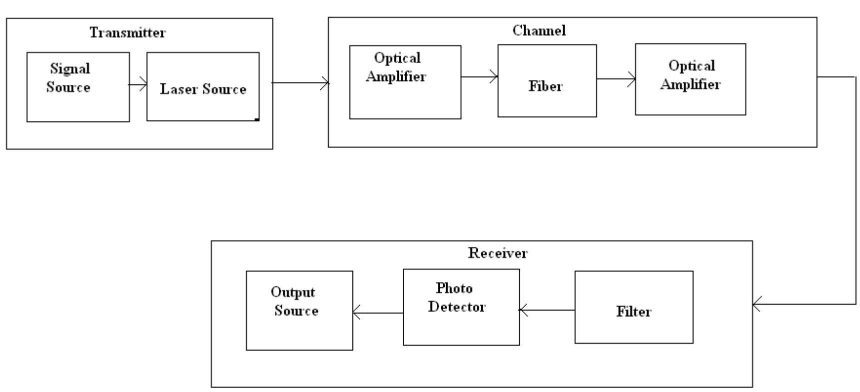

Fig 2: System Layout to analyze FWM Effect

Analysis of Four Wave Mixing versus dispersion is done choosing bit rate of 10, 20 & 40 Gb/s. The fiber dispersion value is varied from 0 to 4 ps/nm/km by parametric run feature used in optsim simulator. The optical power spectrum of the received signal (as shown in Fig. 3) is compared with different bit rates by varying dispersion.

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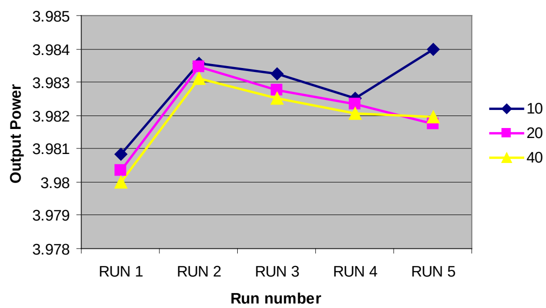

Fig. 3: Comparison of Output Power Vs Dispersion at varying Bit Rates

From the Fig. 3 we observe that there is not much change in output power if we go from lower to higher bit rates. So higher bit rate (40 Gb/s) is more preferable.

Using simulation setup, the value of BER, eye diagrams and Q-factor is measured at the receiver output by using an electrical scope, Q estimator and BER estimator.

The Optical Spectrums for at Run 3 (Dispersion = 2 ps/nm/km) at varying bit rates is as shown in Fig. 4 to 6:

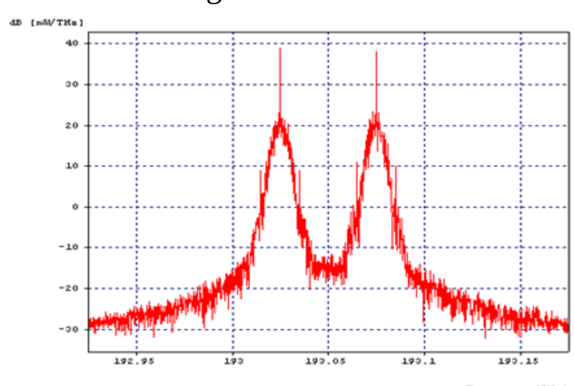

Fig. 4: Optical Spectrum at 10 Gb/s.

Fig. 4 shows the input optical spectrum obtained when we use bit rate of 10 Gb/s. While Fig. 5 is obtained at bit rate of 20 Gb/s.

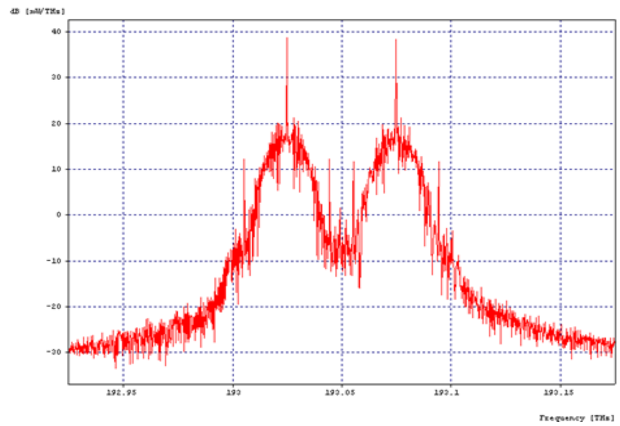

Fig. 5: Optical Spectrum at 20 Gb/s.

Fig. 6 represents the input spectrum at bit rate of 40 Gb/s. The four wave mixing effect is clearly seen in this spectrum as the spectrum gets wider at increased bit rate.

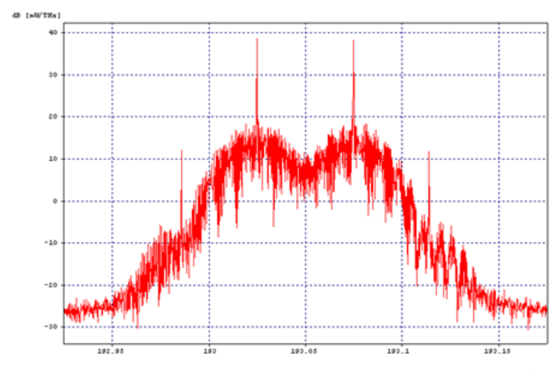

Fig. 6: Optical Spectrum at 40 Gb/s.

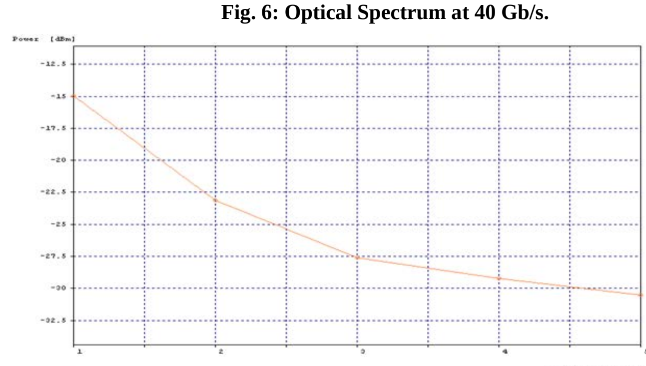

Fig. 7: Correlation Diagram of Optical Power at Power & Four Wave Mixing Product

Fig. 7 shows Correlation Diagram of Optical Power at Power & Four Wave Mixing Product at different run numbers with varying bit rate. From this diagram we can observe that as

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dispersion is increased from 0 to 4 ps/nm/km, the power gets decreased.

4. EFFECT OF DISPERSION ON FWM

In the simulation, Eye diagram is the methodology used to evaluate the performance of the system. The important parameters of eye diagram are Quality factor and Bit error rate. Fig. 8 shows effect of dispersion on FWM. Dispersion in FWM and other performance parameters are derived from this eye diagram.

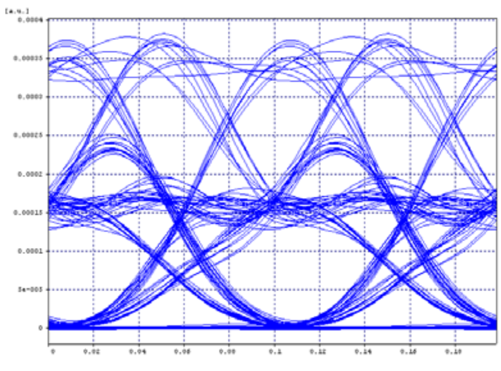

Fig. 8: Eye Diagram for comparing FWM Vs Dispersion

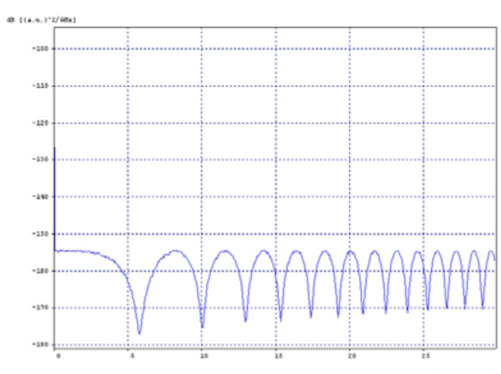

Fig. 9: FWM Vs Dispersion at varying frequencies

Fig. 9 shows dispersion in FWM at varying frequencies. As we move from lower to higher frequency, the dispersion gets increased.

From the eye diagram shown in Fig. 8, different performance matrices like Q value, eye opening, eye closure, BER and jitter are obtained at varying bit rates from 5 to 25 Gb/s as shown in Fig. 10.

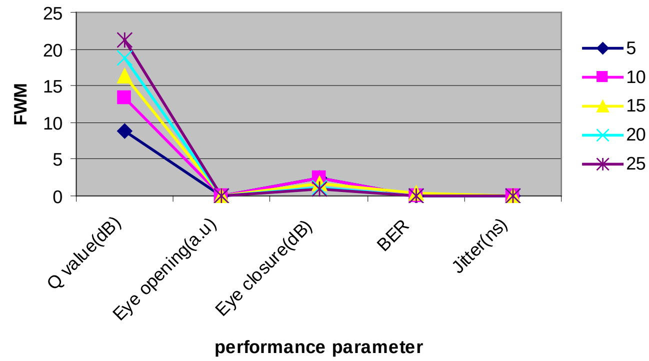

Fig. 10: Effect of FWM on different performance parameters

Fig. 11 shows the combined effect of Distance on FWM, jitter, Q value and dispersion. It is observed that up to 140 km, satisfactory system performance is obtained with minimum jitter, high Q-Value and minimum effect of dispersion on FWM.

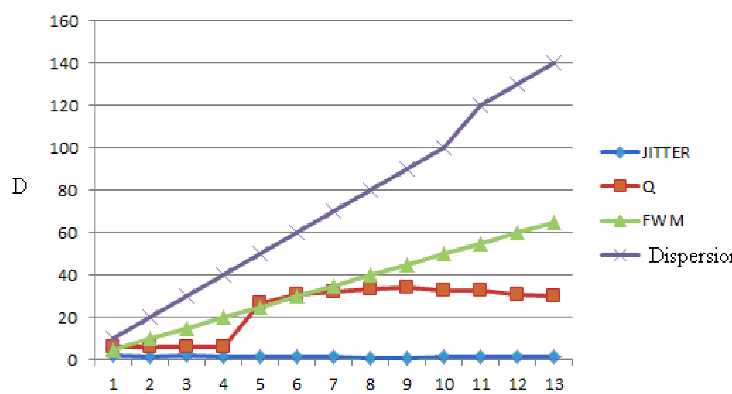

Fig. 11: Effect of Distance (D) on Jitter, Q, FWM and Dispersion

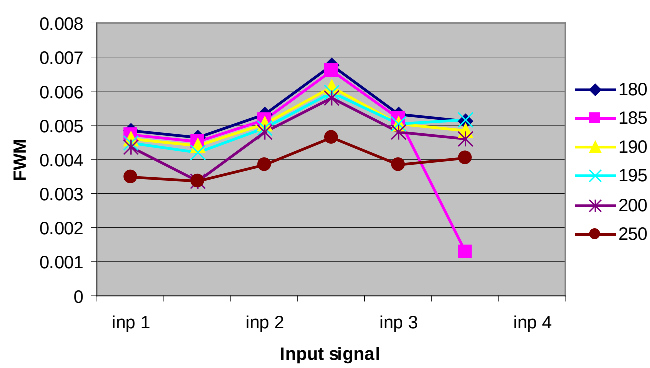

Fig. 12: FWM at different frequencies

Fig. 12 shows FWM output power at different frequencies. From this diagram it is observed that maximum value of FWM power is

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obtained at lower frequency (180 THz) and it is decreased as the value of frequency is increased.

5. RESULTS AND DISCUSSION

In this research work, the design, implementation and performance analysis of FWM in optical communication system on the basis of varying bit rate, dispersion and frequency is presented. The comparison of four wave mixing effect at various values of bit rates and dispersion revealed that there is not much change in output power if we go from lower to higher bit rates. It is also found that a satisfactory system performance is obtained at distance of 140 Km and FWM power is decreased when we increase the frequency.

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