Performance Measures of DWDM System under the Impact of Four Wave Mixing

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Abstract: ***In optical fiber communication the Bandwidth capacity is increased by using Dense Wavelength Division Multiplexing. In DWDM based optical communication systems, fiber nonlinearities are limiting factors that limit the data rate and Bandwidth capacity. Besides this the nonlinear optical effects also degrade the system performance. This system has implemented in the presence of Four Wave Mixing with equal channel spacing. In this paper, the Hybrid Modulator technique, Return to Zero (RZ) pulse generator and Dispersion Compensation Fiber (DCF) have proposed to reduce the Four Wave Mixing (FWM) in equal channel spacing. The single and combined effect of various parameters such as input power, effective area, channel spacing and fiber length have been analyzed to determine the effect of FWM power. This result shows that increasing sequentially the effective area, fiber length, channel spacing and decreasing the input power to suppress the effect of FWM. At the receiver, the Q-Factor, BER and FWM power are estimated using Opti-system software.***

Keywords: FWM-Four Wave Mixing, DWDM-Dense Wavelength Division Multiplexing, Equal Channel Spacing , BER-Bit Error Rate, DCF- Dispersion Compensation Fiber

1. Introduction

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. In Dense Wavelength Division Multiplexing (DWDM) multiple channels of information can carry over a single fiber each using an individual wavelength. In DWDM the channels are closely spaced and the channel spacing is reduced as 1.6nm. In DWDM system, the optical fiber under high data rates suffers from some of the undesirable effects that influence the system efficiency and degrade the system performance. FWM is a non-linearity which degrades the system performance. When two or more signal travels in a fiber, interaction between the wavelengths and generated a new signal. It can limit the channel density and the data rate. The FWM product is increased by increasing the input power. When new frequencies fall and overlap the original frequency, it causes sharp crosstalk between channels passing through an optical fiber. Degradation becomes very severe when the number of WDM channels increase and have small spacing. Several techniques have been used to suppress the effect of FWM crosstalk and enhance the signal output. Four Wave Mixing can be reduced by using unequal channel spacing, decreasing the input power, decreasing number of channels, increasing the channel spacing. Jameel Ahmed et al.[2] proposed various factors which influence FWM, such as channel input power, spacing between channels, dispersion of fiber, operating wavelength and refractive index etc. FWM signals can be removed by decreasing phase coherence between channels, decreasing input power per channel, increasing channel spacing or by introducing unequal channel spacing, and decreasing dispersion of transmission fiber. Haider J. Abd et al.[3] proposed a priority-based parameter sequencing order to reduce the FWM effect in the WDM system and enhance the system performance. The effect of FWM power is determined by analyzing various parameters and calculated theoretically. Fabrizio Forghieri et al. [15] proposed a design for channel spacing allocation to reduce the impact of FWM crosstalk. It was shown for a 10 Channel system that the selecting of suitable channel spacing can decrease the FWM crosstalk and increase the power at the receiver to 9dBm. The FWM can be suppressed by Hybrid Modulator technique, RZ pulse generator and Dispersion Compensation Fiber (DCF). RZ pulse generator has larger peak power, high signal to-noise ratio and lower bit error rate than that of NRZ encoding. It has two transitions per bit and has no self-clocking. It also offers better immunity to fiber nonlinear effects because of high peak power. In this paper, we proposed the both single and combined effect of various parameters such as input power, channel spacing, effective area and fiber length have been analyzed to reduce the FWM power. The result shows that the combined of four parameters is the best approach to reduce the FWM power. The output was verified by using the Opti-system software.

2. Methodology

The 120Gbps DWDM system has been implemented in the presence of Four Wave Mixing (FWM) under the impact of equal channel spacing. The simulation set up is consisting of eight CW lasers externally modulated by 15Gbps RZ data for each channel. The Hybrid modulator is consists of Phase modulator, amplitude modulator and Mach-Zehnder modulator. Phase mismatch is introduced in phase modulator which constructively and destructively added to the amplitude modulator. In Mach-Zehnder modulator, when a voltage is placed across the waveguide its index of refraction is changed, causing a phase delay proportional to the amplitude of the applied voltage. A booster amplifier is used to increase the optical output of an optical transmitter just before the signal enters an optical fiber. An EDFA amplifier is used to restore (regenerate) the optical signal to its original power level. An optical pre-amplifier is used at the end of the optical fiber link in order to increase the sensitivity of an optical receiver

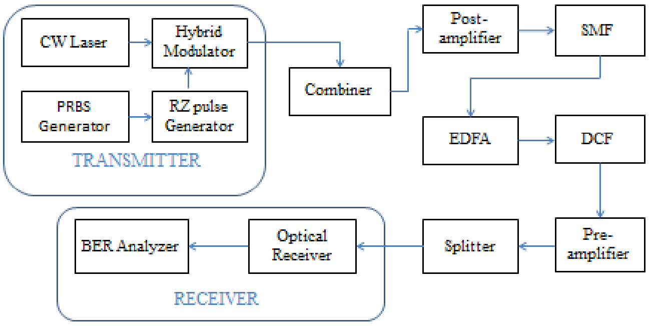


Figure 1: Simulation setup of DWDM system to reduce FWM

The combiner is used to combine the eight channels. Then the Single Mode Fiber (SMF) is used to long distance communication with an optical span of 100km and Dispersion Compensation Fiber (DCF) is used to neglect the negative dispersion and to introduce phase mismatching in the signals. At the receiver, the Q-factor and BER is estimated.

Table 1: Simulation Parameters

Parameters	Values
Frequency operational range	193.1-193.8 THz
Bit rate for per channel	15Gbps
No. of channels	8
Laser power	1dBm
Channel spacing	100 GHz
Fiber length	100km
Effective area	64 μm^2

3. FWM Reduction using Different Parameter

The purpose of this work is to highlight the major drawbacks of modern optical communication systems, which is the FWM that it has a significant effect on WDM system performance. To analyze the FWM behavior under the effect of single and combined of more than one parameters.

3.1 Case 1

In this case we investigated the effect of single and combined effects of two parameters for all identified parameters on the performance of FWM power. For single parameter the effective area is chosen for reducing the FWM power. Figure 2 illustrates the relationship between the FWM power and effective area. Increasing the effective area of the fiber can decrease the FWM effects for all types of fiber. The main reason for this behavior is that increase the effective area of the fiber leads to decrease the laser input power inside the fiber. The lower input power gives the minimum the FWM products.

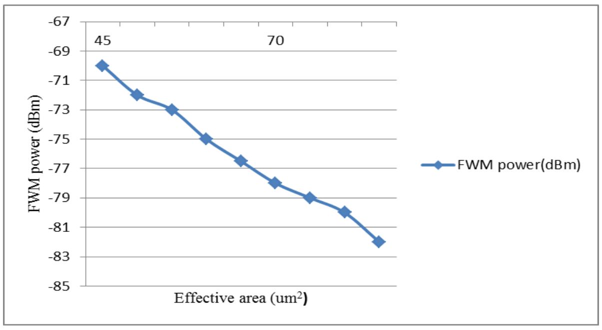


Figure 2: FWM power against effective area

Here, FWM power is reduced as -82dBm with increasing the effective area.

The second parameter is chosen for reducing the FWM power is decreasing the input power. Figure 3 Shows that the FWM power against input power.

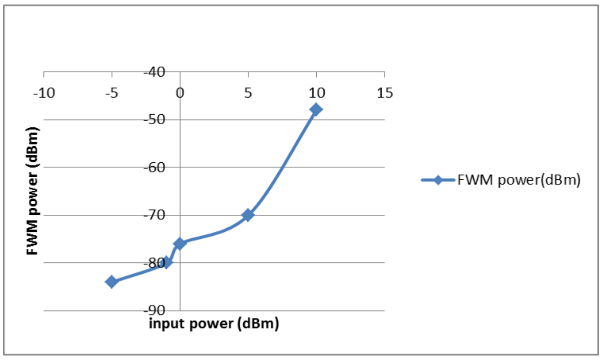


Figure 3: FWM power against input power.

The non-linearity is depending upon the input power, so the power is decreased the FWM power is also decreased. Here, the FWM power is reduced as -86dBm.

The third parameter is chosen for reducing the FWM power is increasing the fiber length. Figure 4 Shows that the FWM power against fiber length.

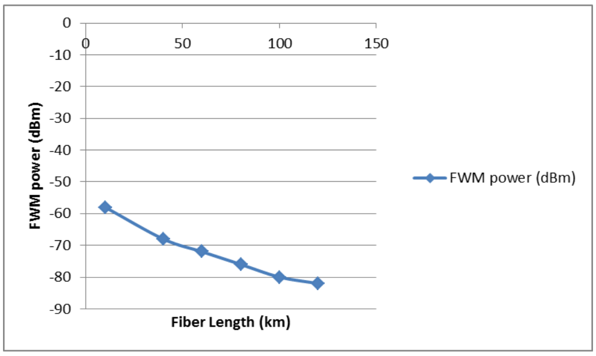


Figure 4: FWM power against fiber length.

When the fiber length is increased, FWM power is decreased and the FWM power is reduced as -84dBm.

The combined of two parameter with decreasing the input power and increasing the channel spacing is analyzed to determine the effectiveness of the FWM power

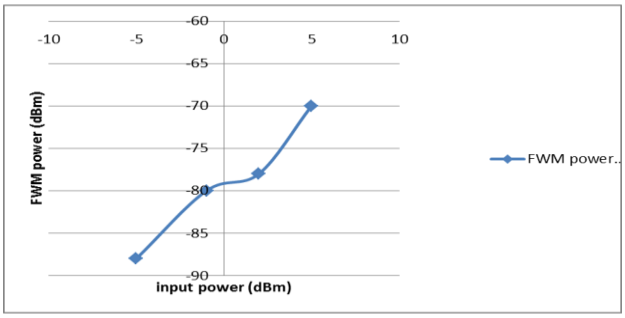


Figure 5: FWM power against input power with increased channel spacing.

3.2 Case 2

In this case the combined effect of three parameters such as increasing the effective area, increasing the channel spacing, and increasing the fiber length can reduce the FWM power.

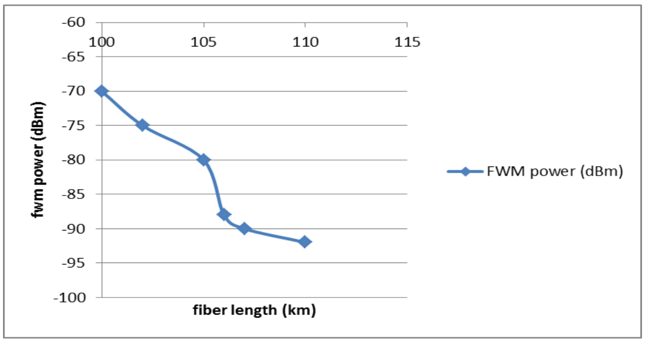


Figure 6: FWM power against fiber length increased effective area and channel spacing.

3.3 Case 3

In this case, the combined effect of four parameters such as increasing the effective area, decreasing the input power, increasing the fiber length, and increasing the channel spacing on the behavior of FWM power.

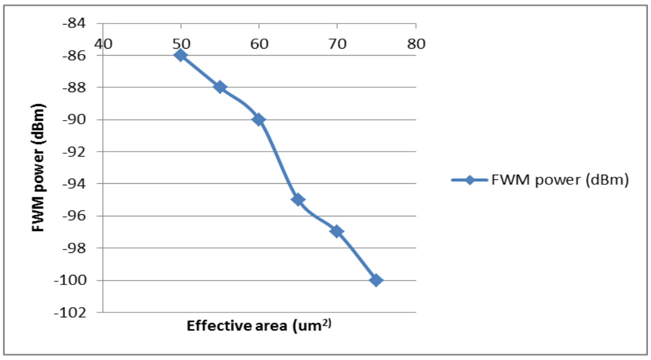


Figure 7: FWM power against effective area with increasing channel spacing, increasing fiber length and decreasing input power

Here, the FWM power is reduced as -100dBm. Minimizing the FWM power will increase the system performance.

Table 2: Analyzing various parameters to reduce FWM power

Parameters	FWM power (dBm)
Effective area	-82
Input power	-86
Fiber length	-84
Channel spacing + input power	-88
Channel spacing + Effective area + fiber length	-92
Channel spacing + Effective area + fiber length + input power	-100

From this Table 1, the combined of four parameters gives the best reduction of FWM power compared to single and combined of two, three parameter. So reducing the FWM in the equal channel spacing will increase the system performance.

4. Result and Discussion

Simulation software Opti-system 7.0 is used in order to evaluate and compare the performance of the proposed DWDM system with the presence of Four Wave Mixing under the impact of equal channel spacing. The Q-factor and BER is calculated at the receiver by using BER analyzer. Compared the Q-factor with [5] the proposed methodology gives the better result because of reducing the Four Wave Mixing (FWM) by using Hybrid Modulator technique, RZ pulse generator and Dispersion Compensation Fiber (DCF).

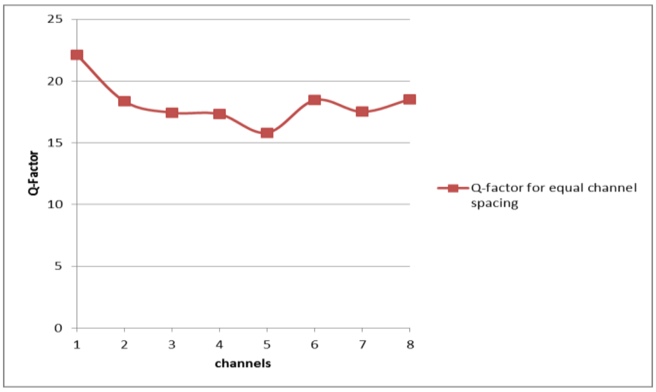


Figure 8: Q-factor of 120Gbps DWDM system of different channels in the presence of FWM with equal channel spacing.

Increasing the Q-factor will increase the system performance. When the presence of FWM is low, the system performance as well as the Q-factor becomes high.

The BER is calculated from the Q-factor by using the formula,

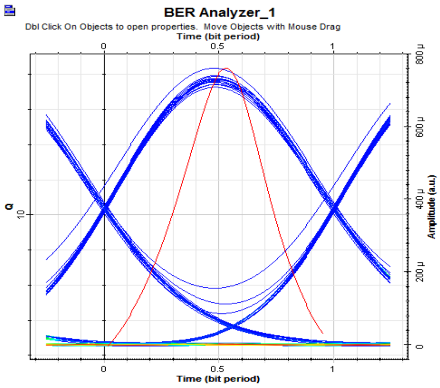
$$\text{BER} = \frac{1}{2}\,\text{erfc}\left(\frac{Q}{\sqrt{2}}\right) \quad (1)$$

Table 3. BER for equal channel spacing in the presence of FWM.

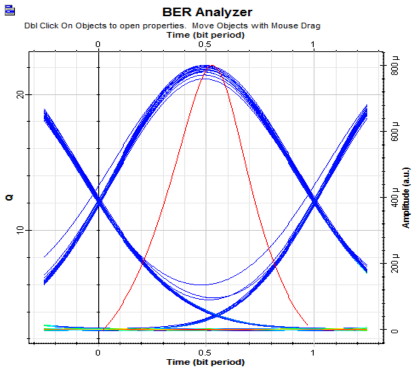
Channels	Q-factor	BER^*e^{-50}
1	22.1389	$5.7233e^{59}$
2	18.3589	$1.21445e^{25}$
3	17.4358	$1.85759e^{18}$
4	17.318	$1.42966e^{17}$
5	15.8091	$1.04435e^{6}$
6	18.4551	$2.16108e^{26}$
7	17.5086	$5.31748e^{19}$

8	18.5194	$6.52089e^{27}$

The BER is calculated for eight channels in the presence of FWM with equal channel spacing. The BER is reduced due to the presence of Four Wave Mixing is decreased. A digital receiver makes a bit by bit decision on the presence of “1” or “0”. When the Eye opening is large the signal send to the receiver is good and the distortion is less.



Channel 1



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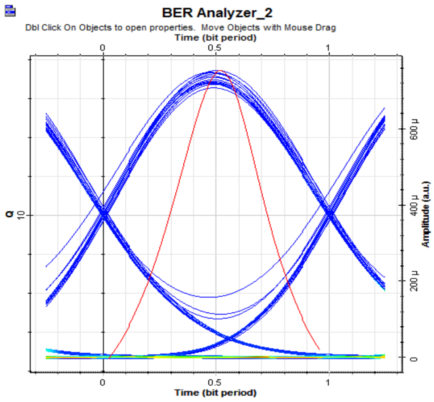
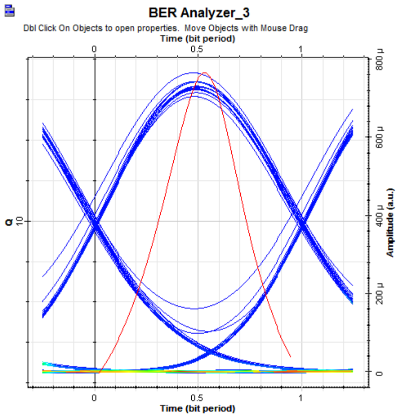
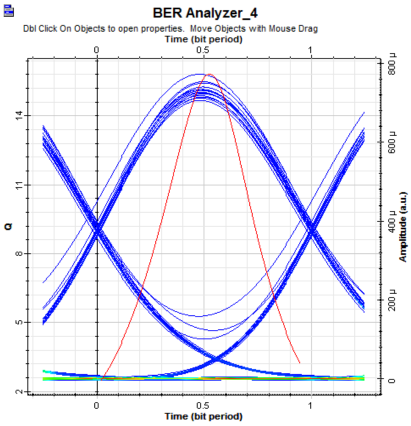


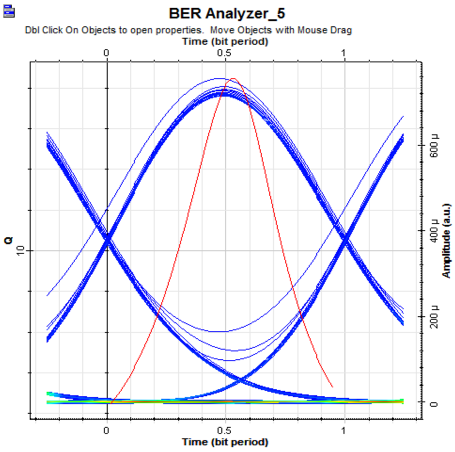
Channel 3



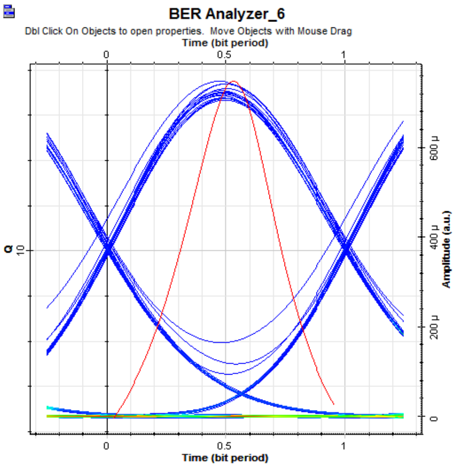
Channel 4



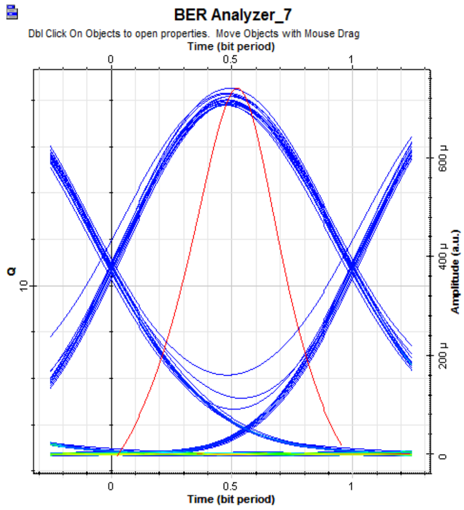
Channel 5



Channel 6



Channel 7



Channel 8

Figure 9: Eye diagrams of 120Gbps DWDM system with equal channel spacing of 100 GHz with optical span of 100 km in the presence of FWM.

5. Conclusion

An implementation of 120Gbps DWDM system in the presence of Four Wave Mixing (FWM) with equal channel spacing has been evaluated to estimate Q-factor, BER and FWM power. System performance is increased and the BER is decreased because of reducing the FWM by using the Hybrid Modulator technique. The single and combined effect of various parameter such as effective area, input power, channel spacing and fiber length have been analyzed to determine the effectiveness of FWM power. The combined of four parameter i.e., increasing the effective area, decreasing the input power, increasing the fiber length, and increasing the channel spacing gives the best reduction on the FWM power. The FWM power is reduced as -100dBm. By reducing the FWM, the system performance is increased and also communicates long distances with high data rate.

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