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# An Improved Methodology to Optimize Four Wave Mixing Effect in 32*40 Gbps DWDM Optical Systems

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**ABSTRACT**: Dense Wavelength Division multiplexing (DWDM) is a technology that utilizes a composite optical signal carrying multiple information streams. The performance of DWDM is degraded by non-linear optical effects. They are Cross phase modulation (XPM), Self phase modulation (SPM), four wave mixing (FWM), stimulated brillouin scattering (SBS) and stimulated Raman scattering (SRS).In this paper we analyze the performance of Dense Wavelength Division Multiplexing (DWDM) system for symmetric dispersion compensation scheme for 32 channel 40gbps at RZ modulation scheme for long distance optical transmission system. Depending on all these effects, an optimized DWDM system is designed using optisystem simulation tool to reduce FWM effects.

**KEYWORDS**: Dense Wavelength Division multiplexing, *four wave mixing, Dispersion compensation fiber, RZ, EDFA,optisystem12,* Bit error Rate (BER).

## I. INTRODUCTION

In Dense Wavelength Division Multiplexing (DWDM) multiple channels of information can Carry over a single fiber each using an individual wavelength. 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. Four Wave Mixing can be reduced by using unequal channel spacing, decreasing the input power, decreasing number of channels, increasing the channel spacing[1]. In recent trends radio over fiber (ROF) techniques may use for achieving the high data rates, low loss. ROF system also use ultra wide band provided by optical fiber. The main benefits of ROF are low attenuation loss, large bandwidth, immunity to radio frequency interference, reduced power consumption, multi operation and multi service operation, dynamic resource allocation[2].In the present paper, we have examined the impact of four wave mixing (FWM) for 32 channel 40GBPS WDM network over the optical fiber link for 480 km.

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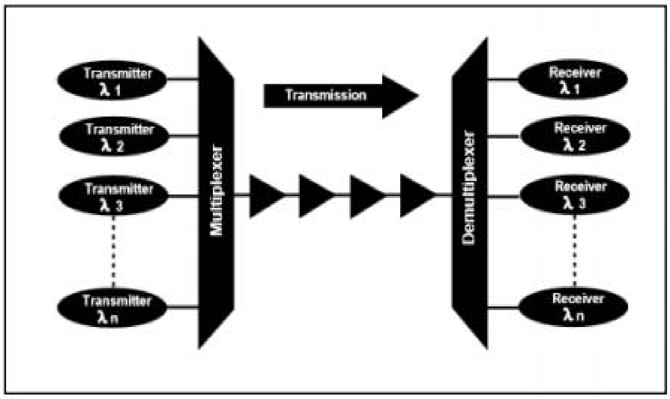


Fig 1: DWDM System of n Channel

## II.THEORY

### 1.1 Optical Nonlinearities

The nonlinear interactions in optical fibres depend on the transmission length and the cross-sectional area of the fibre as shown in equation 1. The longer the link length, the more the interaction and the worse the effect of nonlinearity [3].

$$Le = \frac{1-e^{\cdot}}{\alpha} \quad \text{.........} \; (1)$$

This effect is responsible for self-phase modulation (SPM),cross phase modulation (XPM) and four wave mixing (FWM). The other two important effects are stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS).

### 1.2 Four Wave Mixing

Four wave mixing (FWM) is the important nonlinear effect arises when two or more pulses transmit through same fiber. FWM is a phenomenon that occurs in the case of DWDM systems in which the wavelength channel spacing are very close to each other. This effect is generated by the third order distortion that creates third order harmonics. Hence the name four wave mixing.

In general, the number of crossing product K, for N number of input channel is given by [3]

K = N2 /2*(N-1) (2) …………(2)

Equation (2) shows that non linear effect FWM increase as number of channel in DWDM system increases. As N increases, K increasesrapidly. Two factors strongly influence the magnitude of the FWM products, referred to as the FWM efficiency. The first factor is the channel spacing; where the mixing efficiency increases dramatically as the channel spacing becomes closer. Fiber dispersion is the second factor, and the mixing efficiency is inversely proportional to the fiberDispersion, being strongest at the zero-dispersion point. In all cases, the FWM mixing efficiency is expressed in dB, and more negative values are better since they indicate a lower mixing efficiency.

The efficiency of FWM and noise performance is analyzed, taking into account the effects of difference channel spacing. To evaluate the efficiency of the FWM

$$\eta = \left[\frac{n2}{Aeff\,D(\Delta\lambda)^2}\right]\text{\^{}}2 \text{.........}(3)$$

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To investigate the relationship between the efficiency and the power of the FWM [6]

$$P_{ijk} = \left(\frac{\gamma^2}{9}\right)\left(d_{ijk}\right)^2\left(p_i p_j\ pk\right)e^{-}\quad L_{ef}^2 \ldots\ldots\ldots\ldots(4)$$

WhereLeff is effective length, d is the degeneracy factor,αis the fiber loss coefficient and L is total fiber length.

## III. SIMULATION SETUP

Our proposed system consists of WDM transmitter, WDM multiplexer, single mode fiber, dispersion compensation fiber, EDFA, WDM demultiplexer, optical receiver, bit error rate analyzer. It supports return-to-zero(RZ)modulation .The Single Mode Fiber (SMF) is used to long distance communication with an optical span of 480km and Dispersion Compensation Fiber (DCF) is used to neglect the negative dispersion and to introduce phase mismatching in the signals**.**

32 channels are used with the frequency starting from 190 THz having frequency spacing of 200Ghz. Ideal multiplexer is used to produce the multiplexed outputand transmitted through the single mode fiber(SMF) having attenuation coefficient and dispersion slope 2db/km and 0.075ps/nm/km. The signal is given to Erbium doped Fiber Amplifier-1 (EDFA) to boost the signal, with a gain of 15dB and noise figure of 6 dB respectively. EDFA's are highly transparent to signal format and bit rate and highly immune to interference effects between different channels.To compensate the effect of four wave mixing dispersion compensating fiber (DCF) is used with attenuation, dispersion and dispersion coefficient 0.5db/km, -80ps/nm/km and -0.3ps/nm2/km respective. The effect of attenuation is minimized with the help of the EDFA-2 same as EDFA-1. Each span consists of 75 km of SMF and 30 km of DCF in order to fully compensate for the dispersion slope and accumulated dispersion in transmission fiber. Now again SMF -2 is connected having same parameters and length that of the SMF-1 . The one end of the SMF and another end of EDFA is given to loops control mechanism. The loop control system has 3 loop.The output of the loop control is given to the one end of the WDM demux[4] .if it is required to increase the transmitting distance then rotate the signal in the loop and increase the number of loops.The total length of the fiber channel is 450 km.In the receiver side the signal is passed through an WDM demux ,detected by photo detector(PIN) having dark current 10nA &resposivity 1A/W .Now this electrical signal is passed through Low Pass Bessel filter of order 4 to remove the noise.Then 3R generator & BER analyzer are used for eye diagram analysis of signal [6][2].

The simulation is performed with RZ modulation using Symmetric compensation technique.

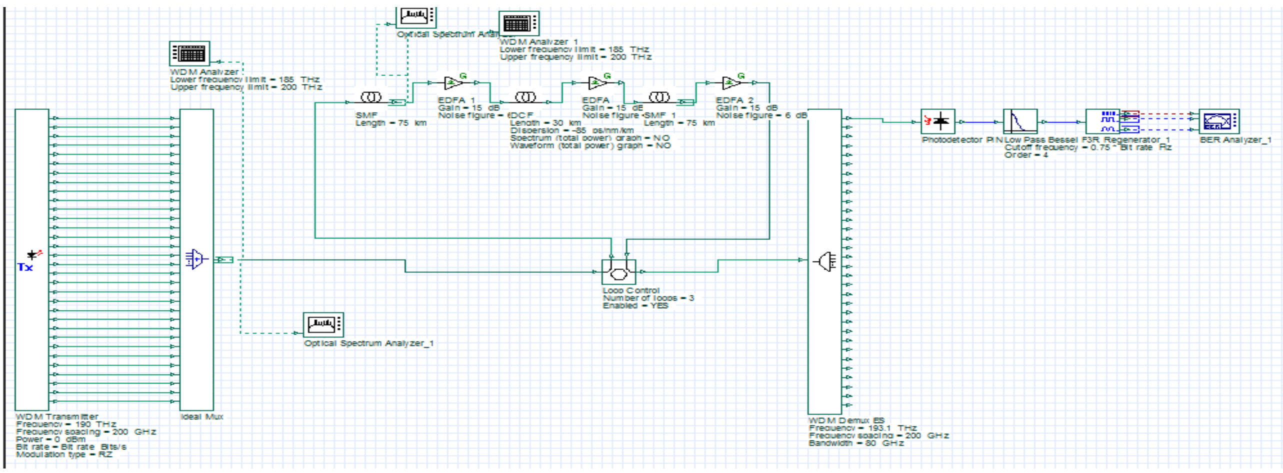

Fig 2: Simulation Model of DWDM setup using Symmetric compensation technique.

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Table 1: Simulation Parameters

| PARAMETER NAME | VALUE |
|---|---|
| Transmission Distance | 480 Km |
| Bit Rate | 40 Gbps |
| Sequence Length | 64 |
| Capacity | 32 Channels 40 Gbps |
| Samples/Bit | 256 |
| Input Power | 3 dBm |

Table 2: Fiber Specifications

| Parameters | SMF Value | DCF Value |
|---|---|---|
| Reference wavelength | 1550 nm | 1550 nm |
| Length | 150 km | 30 km |
| Attenuation | 0.25 db/km | 0.5 db/km |
| Dispersion | 17 ps/nm/km | 80 ps/nm/km |
| Dispersion slope | 0.08 ps/ /km | 0.08 ps/ /km |
| PMD coefficient | 0.5 ps/km | |
| Differential group delay | 0.2 ps/km | |

## IV. RESULT & DISCUSSION

The simulations are done in Optisystem 12.0 simulator& it has been observed that distance is increased three times, yet theperformance parameters (Q-factor, BER and Threshold Value and Eye-Height) possess better value compared to previous model.Thustheproposed technique is good for long haul communication system.

**A.FWM effect for RZ modulation format:-**

For this simulation, input power =0dbm, channel spacing=200GHz,effective core area=70µm and laser line width 0Hz.The signal is analyzed after travelling the distance of 75km and value of OSNR =39.02 at channel1.So RZ is preferable for long distance communication to minimize FWM effects.

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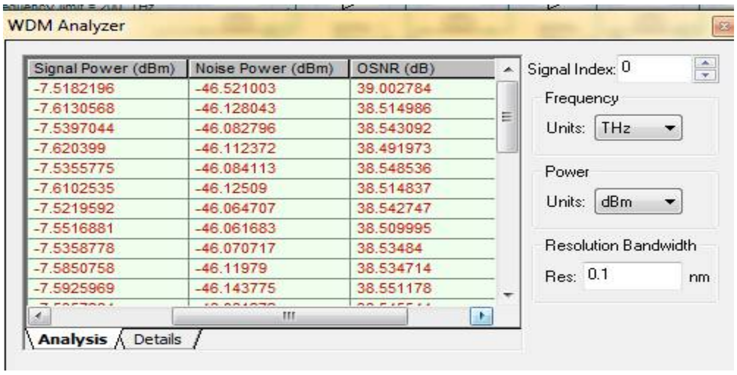


Fig3: WDM analyzer o/p for RZ modulation (wdmmux )

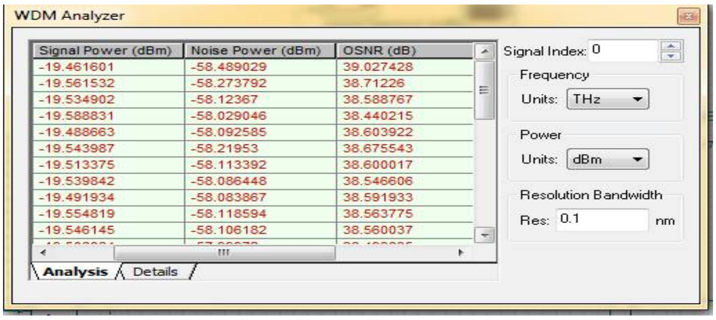


Fig4: WDM analyzer output for RZ modulation (at distance of 75km Length)

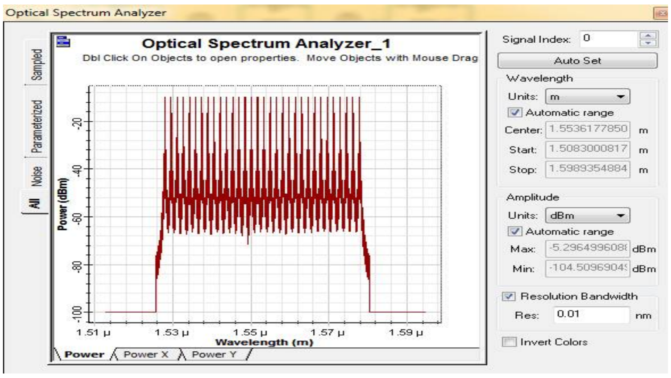


Fig 5: Input Spectrum of SMF of 75 Km Length (RZ Modulation Format*)*

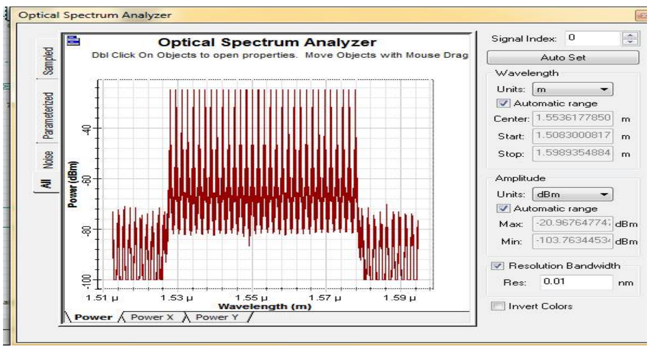


Fig 6: Output Spectrum of SMF of 75 Km Length (RZ Modulation Format*)*

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**B. Eye diagram analysis:**

The eye diagram is also a common indicator of performance in digital transmission systems. The eye diagram is an oscilloscope display of a digital signal,repetitively sampled to get a good representation of its behavior. The eye diagram can also be used to examine signal integrity in a purely digital system—such as fiber optic transmission, network cables.

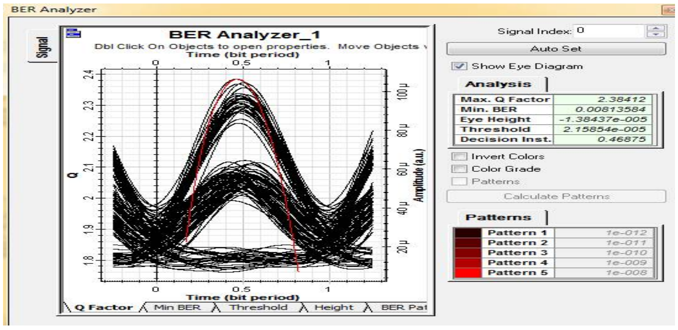


Fig 5: *Eye Diagram and Q-value of link beforeoptimization (at the distance of 450 Km)*

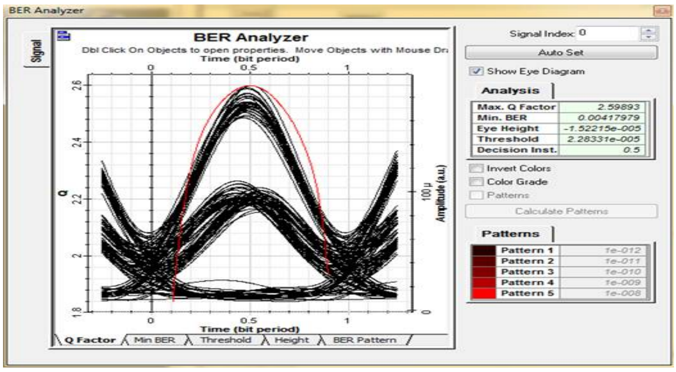


Fig 6: Eye Diagram and Q-value of link after optimization

**C. Q-FACTOR &BER analysis:**

The values of maximum Q factor for all channels decrease with the increase of transmission distance.The bit error rate (BER) is the most significant Performance parameter of any digital communications system. It is a measure of the probability that any given bit will have been received in error.

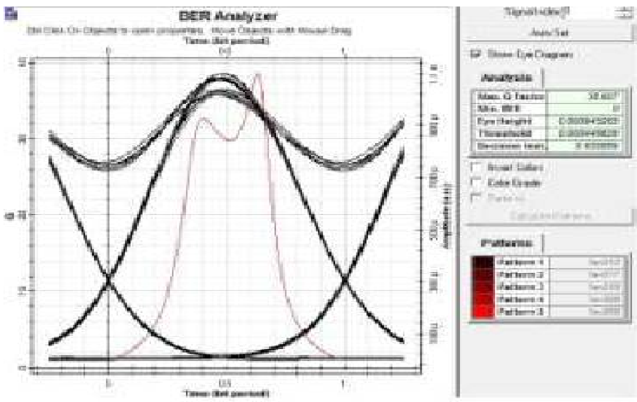

Fig7:*Eye Diagram and Q-value of link after optimization (at the distance of 450 Km)*

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**D. Analysis of FWM Effect on Various CrossSectional Areas of Fiber**

The used parameters areinput power 0dBm, laser line width 0 Hz,channel spacing 200GHz, no modulationformat is selected and the length of the fiberistaken 75 Km. By varying the effective corearea of fiber on 64 $\mu m^2$and 80$\mu m^2$

Table 3: Maximum Side Band Power with Respect to Various Effective Core Areas

| **Effective Core Area(µm2 )** | **64** | **80** |
|---|---|---|
| **Approximate Maximum Side Band Power (dBm)** | **-47** | **-41** |

## V. CONCLUSION

Above analysis conclude that 32 channel DWDM system gives the optimum performance if the input power is 3dBm, modulation format is RZ, channel spacing will not less than 200GHz, Effective core area of SMF is 70$\mu m^2$, laser line width is 0Hz. After using these parameters we simulate the system then our systems performbetter than the previous one.we increase the reach of the DWDM system for long distance than the previous one and the power requirement is also lesser then that of the previous model.For our model Q value of the system is 39.027 which is greater than the previous value which is 38.607. This method offers improved value of performance parameters such as Q-FACTOR, MIN BER and THRESHOLD value.The proposed system may be further analyzed and can be used to obtain better signal at receiving endfor different combinations of SMF length, DCF length and EDFA gain.

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