PERFORMANCE ANALYSIS OF DWDM BASED FIBER OPTIC COMMUNICATION WITH DIFFERENT MODULATION SCHEMES AND DISPERSION COMPENSATION FIBER

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Abstract

Dense Wavelength Division multiplexing (DWDM) is a novel technology that can improve the channel capacity and meet growing demands for bandwidth of the optical fiber communication system. This technology utilizes a composite optical signal carrying multiple information streams. Each information streams transmitted on a distinct optical wavelength onto a single fiber. 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) based fiber optic communication system at different modulation schemes, various power level and different number of data channels. we use the dispersion compensation fiber along with single mode fiber (SMF) for length of 100km at 1550nm to reduce the dispersion of optical signal. The performance of improved detected signals has been evaluated by the analysis of Quality factor and bit error rate (BER). The simulation studies are carried out using optisystem software from optiwave.

Keywords: *DWDM, cross-phase modulation, self-phase modulation, four wave mixing, stimulated Raman scattering, dispersion compensation fiber, NRZ, RZ, EDFA.*

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1. INTRODUCTION

Optical signals of different wavelength (1300-1600nm) can propagate without interfering with each other. The scheme of combining a number of wavelengths over a single fiber is known as wavelength division multiplexing (WDM). Each input is generated by a separate optical source with a unique wavelength. The development of Erbium doped fiber amplifier (EDFA) pushed WDM to the next level, DWDM. The implementation of DWDM would not have been possible without the development of EDFAs. Because these amplifiers operate close to the 1550nm wavelength range, they are compatible with optical fibers that also operate in the same 1550nm wavelength window.

The implementation of DWDM in an optical communication link requires special optical devices and optical modules such as low chirp integrated laser, EDFAs, multiplexer and demultiplexer. An optical multiplexer couplelight from individual sources to the transmitting fiber. At the receiving station, an optical demultiplexer is required to separate the different carriers before photo detection of individual signals. To prevent spurious signals to enter into receiving channel, the demultiplexer must have narrow spectral operation with sharp wavelength cut-offs. The acceptable limit of crosstalk is -30dB. DWDM have some features, they are capacity upgrade, transparency, wavelength routing and wavelength switching.

1.1 Cross Phase Modulation (XPM)

An example of non-linear optical effect is cross-phase modulation. XPM can limit the distance and capacity of DWDM fiber optic transmissions. It is mainly encountered in multi-channel DWDM systems. Distortion and pulse broadening (dispersion) is caused by cross-phase modulation. An increase in dispersion reduces cross-phase modulation. Because of the smaller interaction time between pulses. Single channel systems are subject to self-phase modulation (SPM). When an optical pulse travel through the fiber, an increase or decrease of the light intensity occurs. These intensity variations ultimately affect the fiber refractive index. Because the refractive index is subject to photon intensity. The changes of refractive index affect different part of optical pulse, resulting in phase nonlinearities (chirping).

1.2 Four Wave Mixing (FWM)

In high speed optical networks, the required optical power launched into the individual channels is much higher than the power required in conventional optical systems. Four wave mixing (FWM) is the process whereby optical power from one channel in a multi-channel system is spilled over into an adjacent channel. Four wave mixing (FWM) can be substantially reduced or perhaps completely eliminated through the following steps. They are channel power reduction, increased dispersion and increased channel spacing, fiber photon power peak reduction. The normalized photocurrent variance $\sigma^2$is expressed by given equation

$$\sigma_{FWM}^2 = \frac{2(\sum_{xyz} \mu_{xyz} P_{xyz})}{P_S} \qquad (1)$$

Where $\sigma^2$is the normalized photocurrent variance, P_s is the selected channel optical power, μ_{xyz} is the NRZ modulation factor and P_{xyz} is the FWM power tone generated by xyz channels. Interchange crosstalk effect is caused in DWDM system by FWM non-linearity. The four wave mixing effect is independent of the bit rate. But it is critically dependent on the channel spacing and fiber chromatic dispersion.The unequal channel spacing and dispersion management are used to reduce the four wave mixing (FWM) effect.

1.3 Stimulated Raman Scattering (SRS)

Stimulated Raman scattering is the result of the interaction between vibrating atoms in the crystal lattice and the optical waves. The vibrating atoms absorb some energy from the optical waves and, in conjunction with the vibration energy (characteristic of the atoms in the crystalline lattice), this energy is almost instantaneously reemitted in the form of photons. This emitted photon vibration energy is a kind of light scattering, translated into wavelength shifting. SRS contributes to signal attenuation at operating wavelengths. However, optical amplification is evident at the shifted frequencies. Therefore, the negative effect of SRS must be eliminated during the propagation of the optical waves through the fiber, while the amplification phenomenon at the shifted frequencies must be fully exploited in the design and fabrication of all optical amplifiers.

The stimulated Raman scattering threshold optical power is expressed by given equation

$$P_{0(Th)} = 5.9\times10^{-2}(\lambda)(\alpha)(d^2) \qquad (2)$$

Where $P_{0(Th)}$ is the SRS threshold optical power (W), λ is the operating wavelength (μm), α is the fiber attenuation (dB/km), and d is the core diameter (μm).

1.4 Dispersion Compensation Fiber (DCF)

Dispersion compensation fiber is the special type of fiber used to compensate the signal dispersion by negative value of dispersion coefficient. In DWDM systems DCF is used along with the single mode fiber (SMF). A few hundred meters to a kilometer of DCF can be used to compensate for dispersion over tens of kilometers of the fiber length. To achieve a very high value of negative dispersion coefficient , the core of the compensating fiber has to be doped relatively higher as compared to conventional fibers. The perfect condition for dispersion compensation is expressed by given equation

$$D_1L_1 + D_2L_2 = 0 \qquad (3)$$

Where $D_1 \& D_2$ are the dispersion coefficient of single mode fiber (SMF) and dispersion compensation fiber (DCF), $L_1 \& L_2$are the length of single mode fiber (SMF) and dispersion compensation fiber (DCF).

2. 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.

The WDM transmitter consist the starting frequency of 193.1THz and frequency spacing is about 100GHz. It consists 20 different wavelengths of data channels and input power is 7dBm. NRZ and RZ modulation types are used. The WDM multiplexer consist the bandwidth of 10GHz. The length of single mode fiber (SMF) is 100km and dispersion coefficient is 16.75 ps/nm/km. DCF consists the length of 20km and dispersion coefficient of -83.75 ps/nm/km. Erbium doped fiber amplifier (EDFA) with gain of 35dB & zero noise figure is used after DCF. Link is operating at 10Gbps.

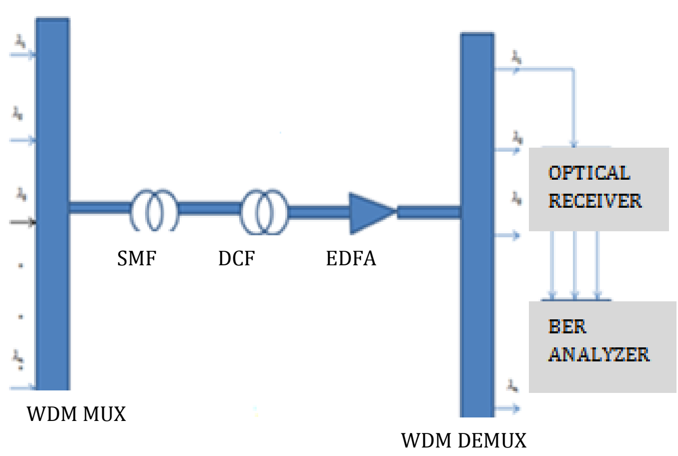
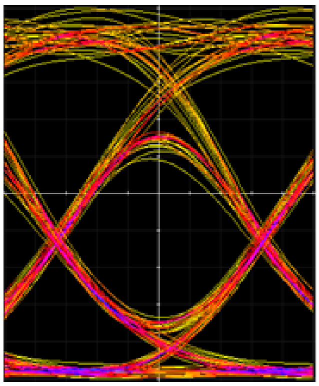


Fig 1

If transmitter consist 20 DWDM channels, 7dBm power and NRZ modulation, then eye diagram & bit error rate, quality factor etc at optical receiver are shown in figure 2.



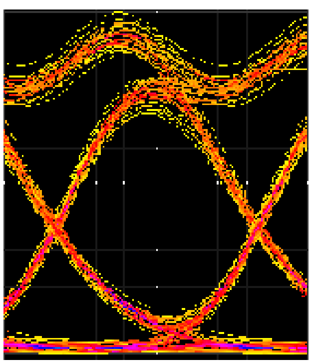
Analysis

Max. Q Factor	4.6268
Min. BER	1.70442e-006
Eye Height	0.000999215
Threshold	0.00155222
Decision Inst.	0.527344

Fig 2: Eye Diagram

Output result for 20 input data channels, 7dBm input power, channel spacing 100GHz and NRZ modulation is used.

If transmitter consist 20 DWDM channels, 7dBm input power and RZ modulation without change of fiber length, then the eye diagram & bit error rate, quality factor etc at optical receiver are shown in figure 3.



Analysis

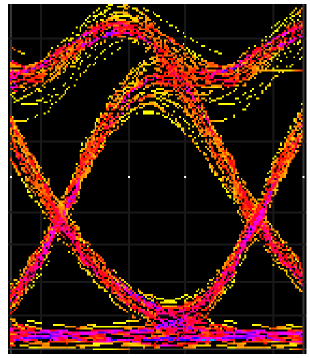
Max. Q Factor	8.78378
Min. BER	7.50674e-019
Eye Height	0.00313739
Threshold	0.00342406
Decision Inst.	0.582031

Fig 3 Eye Diagram

Output result for 20 input data channels, 7dBm input power, channel spacing 100GHz and RZ modulation.

By comparing the figure 2 & figure 3, we can analyze that RZ modulation scheme offer certain advantages over NRZ, as they tend to be more robust against distortions and provide acceptable bit error rate.

The simulation is performed with RZ modulation at various power level and different number of channel counts without change of fiber length. If transmitter consist 12 DWDM channels, 3dBm input power and RZ modulation, then Eye Diagram & bit error rate, quality factor etc at optical receiver is shown in figure 4.



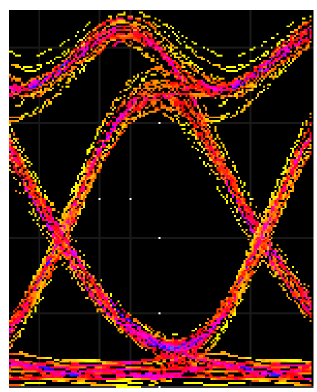
Analysis

Max. Q Factor	7.41189
Min. BER	5.96652e-014
Eye Height	0.00113976
Threshold	0.00143104
Decision Inst.	0.578125

Fig 4 Eye Diagram

Output result for 12 input data channels, 3dBm input power, channel spacing 100GHz and RZ modulation.

If transmitter consist 16 DWDM channels, 5dBm input power and RZ modulation, then Eye Diagram & bit error rate, quality factor etc at optical receiver is shown in figure 5.



Analysis

Max. Q Factor	8.06647
Min. BER	3.4751e-016
Eye Height	0.00190437
Threshold	0.00227074
Decision Inst.	0.585938

Fig 5 Eye Diagram

Output result for 16 input data channels, 5dBm input power; channel spacing 100GHz and RZ modulation.

3. SUMMARY AND CONCLUSIONS

This project presents a performance analysis of Dense Wavelength Division Multiplexing (DWDM) with NRZ, RZ modulation schemes and Dispersion Compensation Fiber (DCF).The transmitter consist of 20 DWDM channels, 7dBm input power, channel spacing 100GHz, fiber length 100km, DCF length 20km and NRZ modulationgives bit error rate (BER) of $1.70442e^{-006}$. The transmitter consistof 20 DWDM channels, 7dBm input power, channel spacing 100GHz, fiber length 100km, DCF length 20km and RZ modulationgives bit error rate (BER) of $7.50674e^{-019}$. The RZ modulation with different channels and power level was successfully simulated. From the above analysis we conclude the performance of RZ modulation is better than NRZ modulation. The bit error rate is greatly reduced by using RZ modulation.The Single mode fiber (SMF) signal dispersion is compensated by using Dispersion Compensation Fiber (DCF) with dispersion coefficient of -83.75 ps/nm/km.

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