NONLINEAR COMPENSATION USING OPTICAL PHASE CONJUGATION FOR 8 CHANNEL MULTIPLEXED TRANSMISSION

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Abstract : Phase-conjugate wave technology has many attractive applications such as optical computing, interferometry, laser gyroscopes, fiber and satellite communication systems. In this work, Optical phase conjugator with dispersion compensating fiber has been proposed. Analysis exposed that the OPC module with Dispersion Compensating Fiber (DCF) in an optical link mitigates the FWM effect and suppress the interaction between propagating wavelength signals at different link length (200km), launched power level and pump wavelength. Moreover, comparison is also made without OPC module (conventional WDM), OPC with DCF and OPC without DCF in terms of Min BER, Quality factor and Eye-Height. It is recognized that OPC module with DCF performs exceptionally well and mitigates FWM with ease of maintenance.

IndexTerms - ***Optical phase conjugator; Dispersion compensating fiber; four wave mixing; Eye patter, Quality factor; BER.***

I. INTRODUCTION

In rapid evolution of optical fiber communication, the need for information capacity carrying systems is more because of extension in services reliant on internet, video on demand and cloud computing [1]. The growth of optical fiber technology is revealed from last few years because of the several advantages such as tremendous transmission capacity, speed, immunity to EMI and security. Nonlinearity of fiber is considered to be the dominant hurdle in the advancement of communication capacity [2]. Wavelength Division Multiplexing (WDM) is a assuring technology to accommodate the demands of multiusers by transmitting data from different sources over the same fiber optic link at the similar time where by individual data channel is carried on its particular distinctive wavelength. Optical fiber nonlinearity issue in WDM systems are self phase modulation (SPM), cross phase modulation (XPM), stimulated Raman scattering (SRS), stimulated Brillouin scattering (SBS), four wave mixing (FWM) and fiber impairments cause degradation in system performance, at high input power [3]. Similarly, Kerr nonlinearity effects are more turbulent at grand input power level. Intensity dependency phase shift generates a new wavelength signal which interreacts with chromatic dispersion and restrict the performance due to kerr non-linearity. In order to obtain long haul transmission, these factors are need to be considered. In multi channel systems, four wave mixing has the strongest mischievous effects [4,5]among all nonlinear effects.Four Wave Mixing (FWM) effect represents the oscillation of refractive index when more than one frequency is concurrently travelling through optical fiber and it generates the new frequency component that can significantly limit the overall performance of wavelength division multiplexing systems. In Wavelength Division Multiplexing (WDM) system (FWM) is one of the exceptional degradation factor as propogationinterreaction between different wavelength signals.

In recent years, to overcome the kerr non-linearity extensive efforts have been contrived in both electrical and optical domains through several nonlinearity schemes [6,7]. Digital back propogation (DBP) [8,9], phase conjugated twin waves (PCTWs) [10,11] and optical phase conjugation [12-15] are the proposed nonlinear dispersion compensation schemes. In optical Fiber network , optical phase conjugation is a promising technology to mitigate fiber dispersion and nonlinear effects. OPC provides unique advantages such as faster temporal response of the nonlinear medium, modulation format transparency and ability of working efficiently on WDM systems [16]. FWM effect deteriorate the WDM system perfoprmance. To encounter the nonlinear effects and pulse broadening issues optical phase conjugation was placed in the mid link [17]. In this work, optical phase conjugator with dispersion compensating fiber has been proposed to mitigate the FWM effect in WDM system.

The paper is methodized as follows: section II illustrates the system design , section III elaborates the results and discussion. Section IV summarizes the conclusion of the current investigation.

II. THEORETICAL BACKGROUND

3.1WDM System

Numerous researches that have been reported till now to mitigate the FWM effects in WDM systems using hybrid modulators, unequal spacing, nonzero dispersion fiber (NZ DCF), bit phase arranged return-to-zero signals, dispersion management techniques and time delay lines in multiplexer and demultiplexers [18-20].

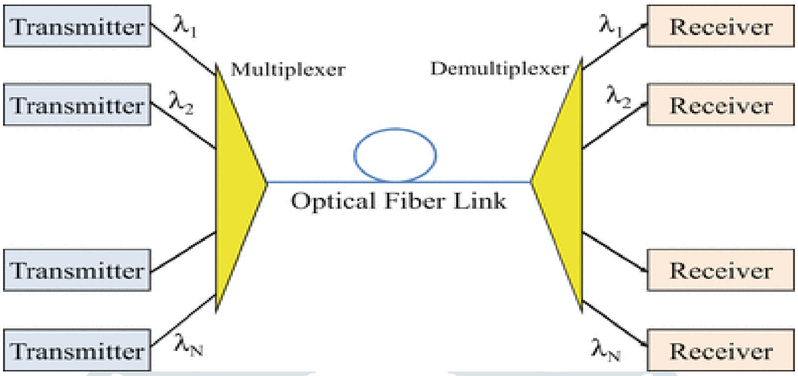

Figure.1 Wavelength division multiplexing technique

Multiplexing is a technic used to transmit various signal is send over the same line. In Wavelength division multiplexing (WDM) system in which a entire information is delivered through multiple carriers over a single fiber and it enables bidirectional communication. When a high power signal passed into a fiber, system performance can be limited by FWM.

3.2 Four Wave Mixing

Four wave mixing is a dominant performance debilitating concern in wavelength division multiplexing systems. FWM takes place in which various optical source of different wavelengths are transmitted through a single fiber, producing a signal of new wavelength [21]. The three frequency components are simultaneously propagate in the optical fiber, then new frequency component is expressed as,

$$\omega_{ijk} = \omega_i + \omega_j - \omega_K \text{ where } (i,j,k= 1,2,3) \qquad (1)$$

due to FWM effect number of side band increases is written as the following equation,

$$M=\frac{1}{2}(N^3-N^2) \qquad (2)$$

where M is the total FWM products and the total number of channels are indicated by N.

III. OPTICAL PHASE CONJUGATION

New methods are being extended to suppress FWM effects in WDM system, one of them is optical phase conjugation. The device that generates phase conjugation of the optical signal is called Optical Phase Conjugator (OPC). OPC is used to backwards the phase propogation direction and phase beam of light, the backward beam is called conjugated beam[22]. Analytically, it is the complex conjugate of the input power signal. Optical Phase Conjugation is the best alternative to mitigate FWM effects. In order to find the optical phase conjugation of the signal OPC is placed in the midmost of the transmission link. After conjugation deterioration appears in the second portion of the link reduce impairments that occurred before conjugation in the first portion of the link. However, the maintenance of transmission modules consisting of OPC is hard and also increase the complexity of the system. In this work, the no. of OPC modules can be reduced for decreasing the system complexity and the combination of OPC module with DCF will increase the system performance.

IV. SYSTEM DESIGN

A WDM system that consisting of 8 channels and 10 Gbps data operated in C band. Here each channel data is regulated individually and multiplexed together and then transmitted. In the designed system, the transmitter section subsist of block of pseudo random bit sequence generator (PRBS) having binary signal, it sends the bit sequence to NRZ pulse generator. The NRZ pulse generator converts the bits into pulses and produce an electrical output and then it is fed to the Machzehnder modulator (MZM), is used for controlling the amplitude of an optical wave.

The CW laser emit light pulse with starting frequency 193.1 THz is used with 10 MHz line width at 0 dbm launched power. The input signal is transmitted through SMF+DCF and EDFA which amplifies the signal so it travel a long distance, optical fiber of length 150km is used. Further the magnified signal passed through an optical phase conjugator. The output attained from optical amplifier is fed to optical receiver via WDM demultiplexing. At the receiver end, photo-detector p-i-n converts the light signal into an electrical signal. Low pass Bessel (LPB) filtrates the electrical signal. The received signal is evaluated using BER analyzer.

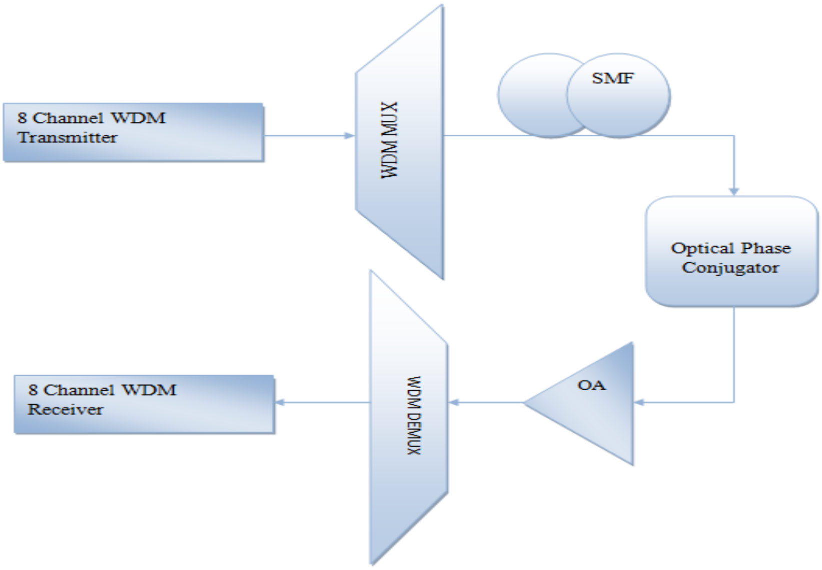

Figure.2 Schematic Diagram of 8 channel WDM system

The layout is simulated using Optisystem 12 and the results are evaluated in terms of Q-Factor and BER.

Table.1 Simulation parameters

PARAMETERS	SPECIFICATION
Reference frequency (nm)	1550
SMF length (km)	150
DCF length (km)	27
Laser frequency (THz)	193.1-193.8
Differential group delay (ps/km)	0.2
Filter Type	Low Pass Bessel
Modulator Type	Mach-zehnder

Table.2 Parameters of OPC module

PARAMETRS	VALUES
Length (km)	0.6
Pump frequency (nm)	1552
Input power (dbm)	5
Nonlinear coefficient $(W^{-1}km^{-1})$	1100
Nonlinear refractive index (n_2)	$26*10^{-21}$

Effective area (μm^2)	10
Attenuation coefficient	0.5

V. RESULTS AND DISCUSSION

In this segment we will cover and dicuss the results attained for designed models depending upon output power, quality factor, eye diagram and BER. Also analysis has compassed done for different link lengths, pump wavelength and input power levels in terms of Q factor, BER and Eye-Height. Figure.3 depicts the FWM effect on WDM system due to propagation interaction between wavelength signals. Reducing the no. of OPC modules will increase the system performance and decreasing the intricacy of the system. Table.4 and 5 describes the configuration of OPC module with and without DCF, input power is varied from -10 to 10 dBm. It is realized that as the power level increases , Q factor decreases because of attenuation, dispersion and nonlinear effects. In case of conventional WDM system, Q factor reported is least as compared to other two configurations in which OPCs are used. Maxmimum Q has been seen for system which incorporated OPC module with DCF and performance of system OPC module without DCF is exhibiting medium Q factor.

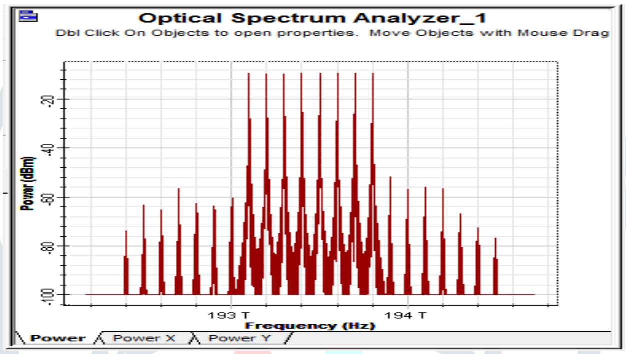

Figure.3a FWM effect in 8 channel WDM system

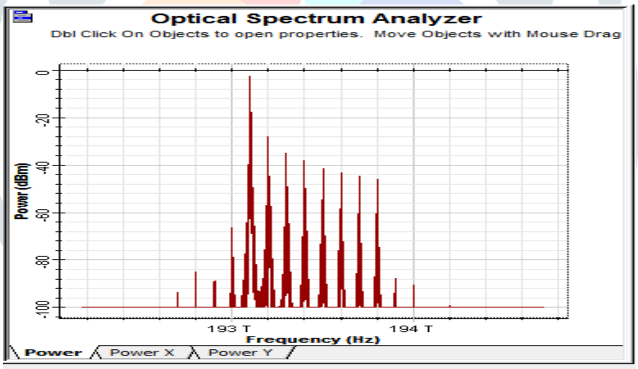

Figure.3b Reduction of FWM using OPC

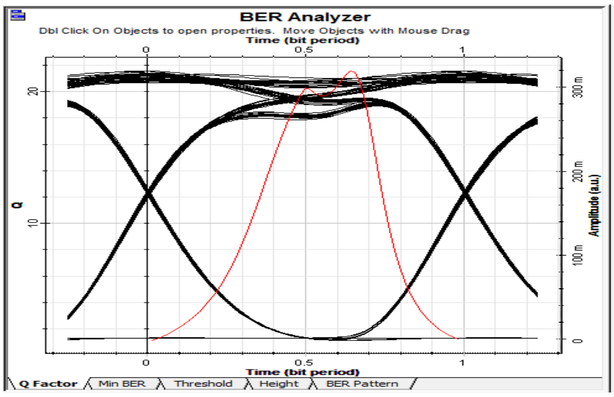

Figure.4 Eye diagram of OPC module with DCF

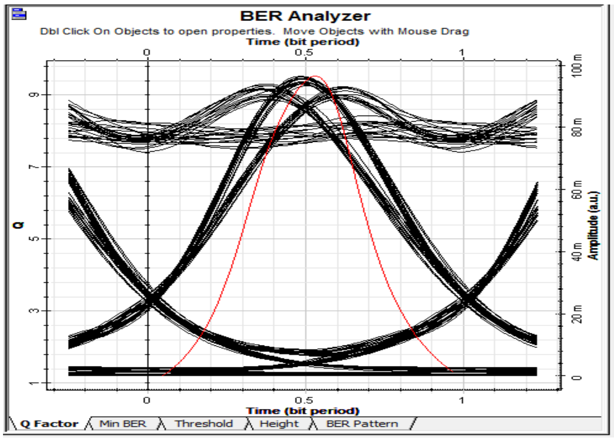

Figure.5 Eye diagram of OPC module without DCF

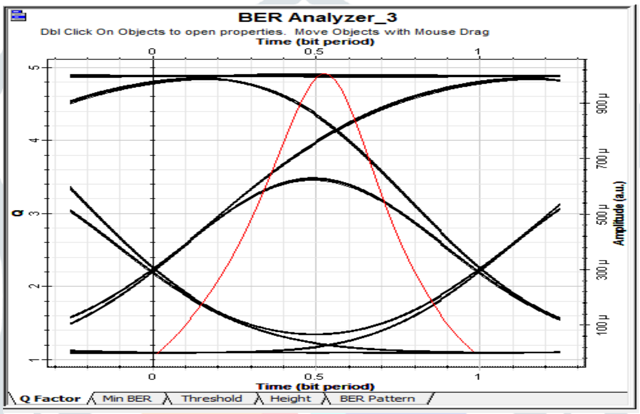

Figure.6 Eye diagram for 8 channel WDM system

Table.3 Comparison of 3 OPC modules

No. of OPC module	Quality Factor	BER	Eye-Height
1	20.8118	10^{-96}	0.247602
2	3.9231	10^{-5}	0.064471
3	2.80465	0.0020	-0.00334

Table.3 depicts the analysis between various forms of OPC module. Clearly at less number of OPC module in a WDM transmission link shows a better performance for a distance of 200 km. However the maintenance of transmission modules consisting large number of OPC modules is hard and also increase the the complexity of the system. So a wayout is required to place the OPC inorder to reduce the complexity and maintenance related concerns.

Table.4 OPC module with DCF values for Varying power

Power (dBm)	Quality Factor	BER	Eye-Height
-10	46.01	0	0.0285763
-5	53.90	0	0.0895979
0	21.71	10^{-105}	0.249389
5	6.24	10^{-10}	0.411319

10	4.20	10^{-005}	0.650615

Table.5 OPC module without DCF values for Varying power

Power (dBm)	Quality Factor	BER	Eye-Height
-10	10.29	10^{-25}	0.0285763
-5	10.35	10^{-25}	0.0895979
0	10.43	10^{-26}	0.249389
5	10.08	10^{-24}	0.411319
10	9.61	10^{-22}	0.650615

Based upon our readings we are able to conclude that out of OPC with and without DCF, OPC module with dispersion compensating fiber is better utilized at lower input power. On the basis of bit error rate, also OPC with DCF gives better performance

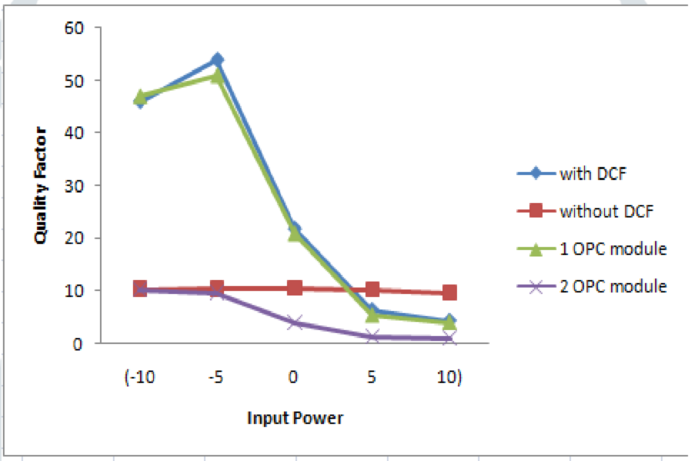

Figure.7 Graphical representation between input power (dBm) and Quality factor

VI. CONCLUSION

In this paper, the suppression of FWM is investigated OPC with and without DCF in 8 channel WDM system. Investigation is done for different distances, pump wavelength and launched power levels. It is recognized that system consisting of OPC with dispersion compensating fiber at low power exhibits best performance in terms of Q factor and BER, also mitigate FWM at maximum extent. Values of FWM are observed for conventional WDM system are -82.11 to -62.2 dB at 0 dBm input power levels. Similarly for the system incorporating OPC exhibit values such as -98.5, -96.2, -91.92, -90.2, -86.4, -87.1 1nd -86.51. OPC without DCF performs less than aforementioned system but better than conventional WDM system. We also compared the performance of optical phase conjugation module in an odd-even allocation. This comparision is made interms of quality factor, BER and eye diagram. It is found that quality factor is dependent of number of transmitted channels, input power and OPC modules. Further it can be proposed in a WDM optical fiber system using Hybrid modules consisting of OPC and FBG .

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