Beyond 4×100 Gbps High Data Rate Long Haul Optical Network with Existence of Nonlinear Impairments

Suliman Khan[*], Farman Ali[†], Shabbir Ahmad[‡], Shahroz Khan[†] and Maqsood Ahmad Khan[†]

Abstract

The long-haul communication having large capability and economical cost set up has now become the major demand in the field of optical fiber communication network and this long-haul large capability optical communication system 4×100 Gbps structure of is examined in this paper. The Q factor of 9.6 and the Bit Error Rate of 1.56 × 10-16 have been achieved with 200 GHz channel spacing and 194.1THz magnitude of (FBG) Fiber Bragg Grating optical filter at 60 µm2 actual zone of the visual fiber. The suggested WDM system Investigative calculations are also verified having a range of 500 km long.

Keywords: long Haul high capacity optical network, Nonlinear issues, cross phase modulation, self-phase modulation, and four wave mixing.

Introduction

The significant aim of a long-haul optical fiber system is to convey the maximum data output over larger expanse deprived of signal renewal. To implement such kind of setup practically over a WDM multiplex system, then fiber nonlinearity is the main boundaries faced to attainable broadcast degrees in optical communication system (A. Napoli, 2016). Additionally, these limitations have direct relation with high data rates optical communication system Agrawal, G. P. (2002). Moreover, higher input optical power level is also needed to be applied into transmission link.

Which may also contribute in transmission performance degradation (Ali, F. M. (2020)). Here the Phase Modulation both Cross (XPM) and Self (SPM) and 4 Wave Mixing (FWM) (F. Ali, Y. K. (2019)), are main foundations of nonlinear deficiencies in optical fiber communication system.

[*] Key Lab of Power Electronics for Energy Conservation and Motor Drive of Hebei Province, Yanshan University, Hebei Province, China. 131@stumail.ysu.edu.cn

[†]Department of Electrical Engineering, Qurtuba University of Science and IT, D. I. Khan, 29050, Khyber Pakhtunkhwa. Pakistan

‡ Department of Electrical Engineering, CECOS University Peshawar, Pakistan.

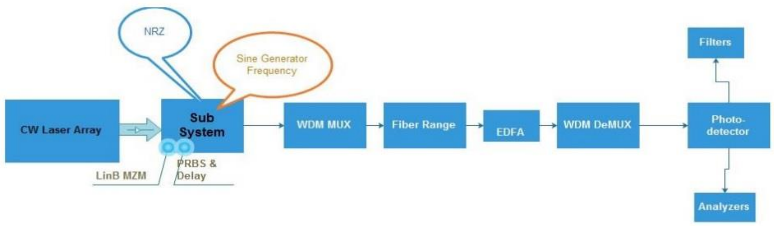

Fig. 1: *Proposed set up of the optical fiber communication system for beyond 400 GHz*

Recent research works in the optical domain are the numeral nonlinearity compensation (NLC) in exclusively exploited coherent multiplexed transmission system (WDM) (F. Ali, Y. K. (2019)), In fiber optic transmission for moderating the result of nonlinear phase nose modelling procedures are done (A. Napoli, D. R. (2016)), the lone phase nonlinear deficiency founded on the mixture of Gaussian model, and WDM design to reach data rate of 40 Gbps more than 240km single channel optical fiber. Though these stated prototypes have compound setup, less security and cost limits. To get the better of these boundaries we suggest an economical set up and normal system arrangement for long haul high data rate system.

The suggested style is verified for advanced data rates i.e. greater than 100 Gbps. Reasonable effects are attained for large data rates, e.g. 1.56 *10-16 BER at 60 um2 and 200 GHz frequency spacing between every channel are recorded, which is acceptable range for the advance communication system. Filtration requirements are fulfilled by EDFA (Eridium Doped Fiber Amplifier) and FBG (Fiber Brag Grating). This paper has been divided into following sections. The Investigative plan clarification in Positions of nonlinear factors based on the system network is explained in section II. Section III proposed model description with block diagram. Discussion of simulation results of the proposed work are explored in Section IV. Section V achieve the experimental and presented work.

Analytical Model

In this section the basic mathematics has been discussed of the proposed work for above 400 Gbps network system which comprise issues

$$F_o = F_i^{j\omega ct} \tag{1}$$

$$E_o = E_i/2[e^{(i\pi v_1(t))/v_\pi} + \gamma e^{((i\pi v_2(t)+v_{bias})/v_\pi))}] \tag{2}$$

of nonlinearity. The output of the laser source is given by (A. Napoli, 2016)).

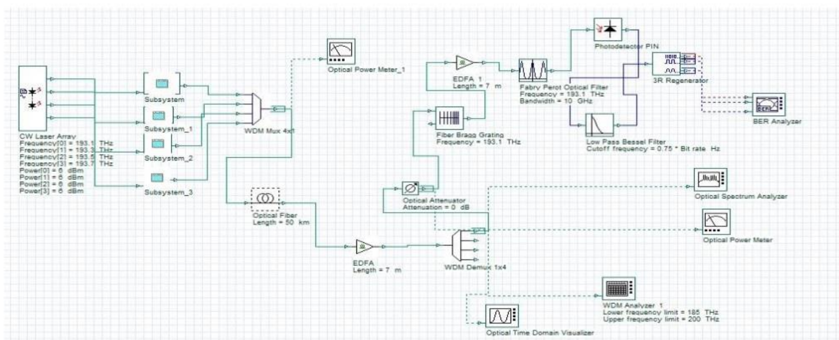

Fig. 2: *Simulation model of the proposed set up.*

The areas of optical are modified by modulator utilizing the pulsations which are made by the channel, explained below as (M. Piels, E. P. (2016)). The *V*1 and *V*2 are given as

$$V_1 = -V_2 = (P(t))/2 \qquad (3)$$

The parameters utilized in the above calculations are input of optical area meant by *Ei*, *Vπ* display the extent of the modulator bias of the circuit discovered by *Vbias*, *V*1 and *V*2 explain the electrical pulses voltage and coefficient of the refractive index denoted by *γ*. Equation (4) represents the mathematical expression for *γ*

$$\gamma = (2\pi N_2)/(\lambda A_e C) \qquad (4)$$

Here *N*2, *Ae*, *λ* and *C* represent non-linear rule of the recompensing fiber, operative zone of the conveying fiber, weighing constant and wavelength correspondingly. The specified plan of the Schrodinger calculation can be described as

$$\partial U/\partial Z + \alpha/2U - \sum_{(i\geq 2)} n^{(i+1)/i!}\beta_i(\partial^i U)/(nT_i) = n\gamma(1 + n\tau_i \partial U/\partial T) \quad (5)$$

Here *U* is the compound extent of the electric region, *T* describe retorted interval, α is the fiber deficiencies, $\beta 1$ is both nonlinear and linear disband term with purpose of *z*. The $\beta 2$ grants linear term while $\beta 3$ signifies nonlinear spreading. The electric dipoles tempted polarization are given by

$$p = \varepsilon_0(x^n E_n!) \quad (6)$$

The factor "0 is free space permittivity and equivalent to 8.85 ×10-12 F/m, *xn* explains order of susceptibility and n is equivalent to 1, 2, 3. . ..

Table 1: *Parameters used at the transmitter end*

Description	Value
Input power	6 dBm
Number of channels	4
Frequency spacing	200 GHz
Sine generator	128 GHz
Pulse generator	NRZ
WDM MUX	128 GHz sample rate
Bit rate	400 Gbps

Table 2: *Elements used for fiber length.*

Description	Value
Ref. wavelength	1553 nm
Length	500 km
Attenuation	0.2 dB/km
β_2	$-18ps^2/km$
β_3	$-3ps^3/km$
Nonlinear refractive index	$2.6 * 10^{-}17$
EDFA	7 m
Dispersion	17 ps/nm

The closing component *En* indicates electric field. Initialize term of the nonlinearity starts from *x*3 called third order susceptibility, so this defines that both nonlinearity and order of susceptibility have direct nature. This section follows briefly presentation the mathematical model of the proposed scheme.

Proposed Network Architecture

The planned style of the long haul high capacity optical network is shown in Fig.1 Array of lasers is connected to duo-binary advance modulation scheme of the long haul large data rate system. Subsystem contains two LiNb, Mach Zehnder Modulator (MZMs) and Two Non Return to Zero (NRZ), one sine wave generator and one Pseudo-Random Bit Sequence Generator. To transmit optical signals over Single mode fiber with different wavelengths we mount WDM Mux. Fiber consist of 0.2dB/km constant loss which increases with increase in length. Hence to compensate such losses. After each 100km of loop we use EDFA amplifier in the system. After de multiplexing the optical signals are adapted into electrical signals by engaging the photo detectors at the receiver end. Also in the receiver part BER analyzer and filter are coupled for the purpose of to detect the quality of the received signals and to remove the noisy data. The model consists of different parameters with various amplitudes.

Table I shows the use parameters of the sender with their values. Name of parameters and their values used in Optical fiber are listed in Table II. Information contains by Fig. 4. are related to OSNR (optical signal to noise ratio) and nonlinear effective area of the optical fiber.

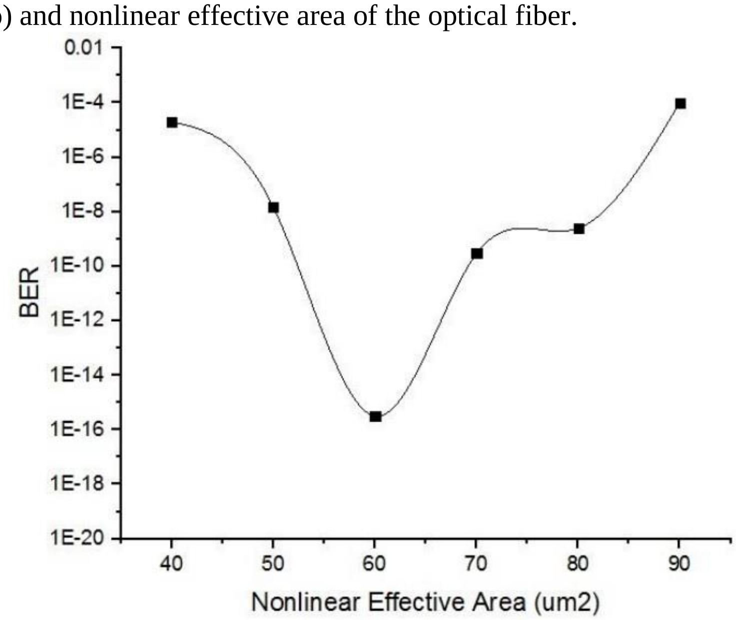

Fig. 3: *Nonlinear effective area against BER.*

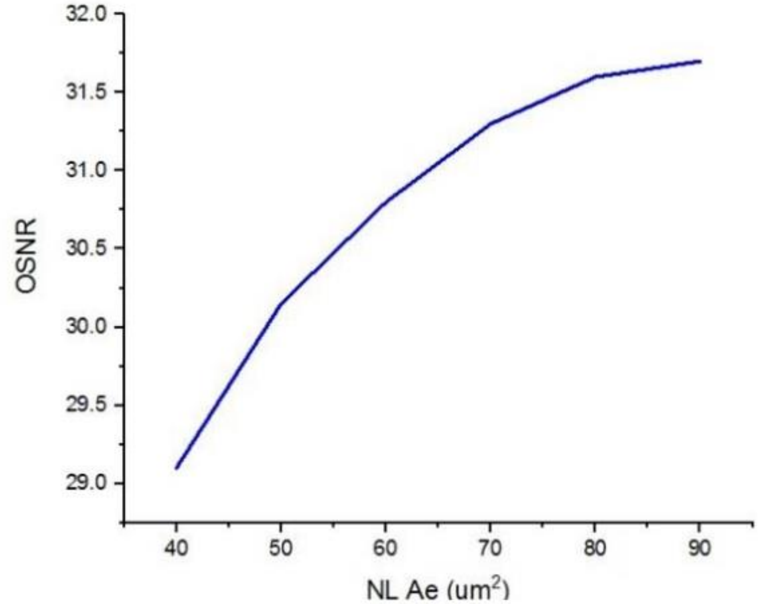

Fig. 4: *Effective area against OSNR.*

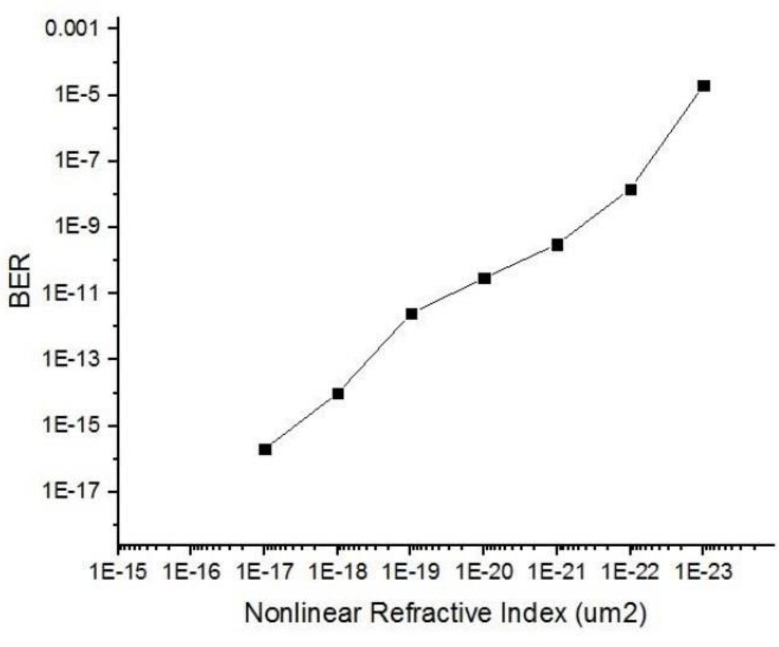

Fig. 5: *Nonlinear refractive index against BER.*

Similarly, Receiver end consist of the following parameters as shown in the tables 1, 2 and 3 some of the mention parameters are kept constant while others are varied like nonlinear refractive index, nonlinear effective area, reference wavelength, linear and nonlinear dispersion and dispersion slope. The better results are gained at 1553 reference wavelength, 2.6*10-17refractive index, and 60 um2 nonlinear effective area of the fiber for long haul optical communication system.

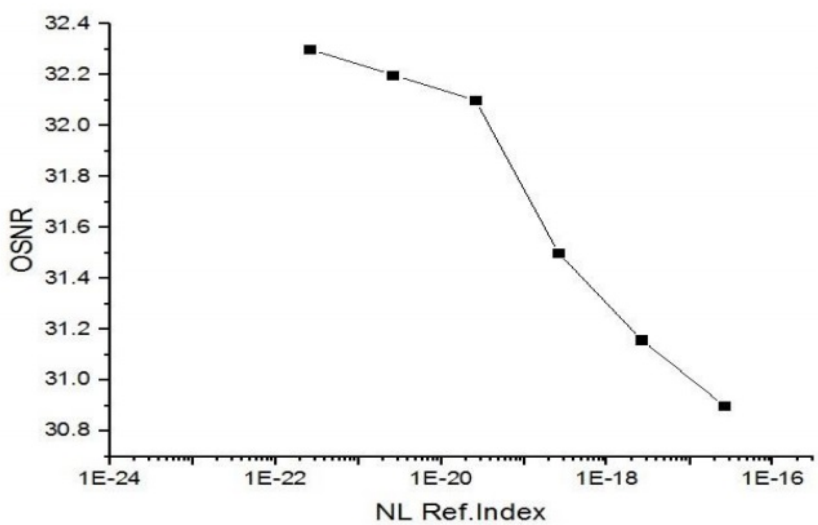

Fig. 6: *Information related to nonlinear refractive index and OSNR.*

Table 3: *Parameters used at the receiver end*

Description	Value
Filter order	2
FBG	194.1 THz
Photo detector	10nA dark current
3R regenerator	400 GHz
Low pass filter	0.75*400 Gbps
WDM DeMUX	1*4

Simulations and results

The experimental setup is designed in Optisystem. In addition to that the results are drawn in origin graphical software. The simulation model is shown in Fig. 2. in which the used parameters are explained in above tables.

Fig. 3. results settled on various values of NL efficient field opposite to BER furthermore the consequence explained that the planned act has good performance on 60 $\mu m2$ nonlinear effective area compared to other ranges of the effective area. Hence except 60 $\mu m2$ effective area due to high nonlinearity system performance becomes down.

At 2.6 ×10-17 nonlinear refractive index the proposed network gives satisfactory results which are practically presented in graphically format as shown Fig. 5. which contains data results of nonlinear refractive index against BER. In other words, the effect of XPM, SPM and FWM nonlinear are very less at nonlinear refractive index 2.6 ×10-17 compare to other values of nonlinear effective area.

Fig. 6. consist of graphical results among NL refractive index and OSNR as shows Graphical results between Q-factor and input power in dBm are given in Fig. 7. which explains the efficient results at 6 dBm for optical fiber long distance communication and high data rate. Above 6 dBm launch power the effect of SRS and SBS nonlinearities are increased which degrade system outcomes. Fig. 8. describe the relation among length of optical fiber and BER. The results clearly clarified that system face less nonlinear issues at lower cover path as the length of optical fiber increased FWM, XPM and SPM nonlinearities make the system data noisy due extra generated frequencies.

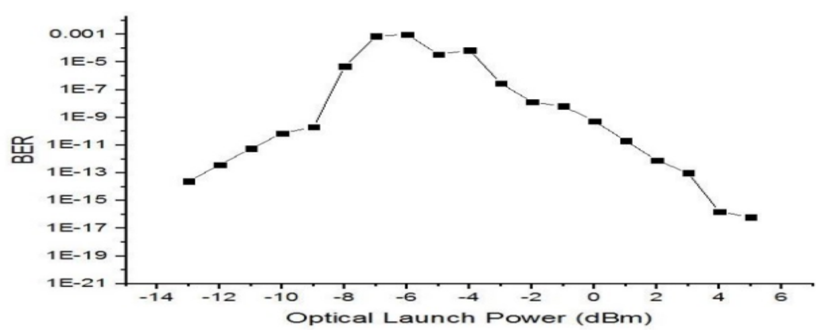

Fig. 7: *Launch power against BER*.

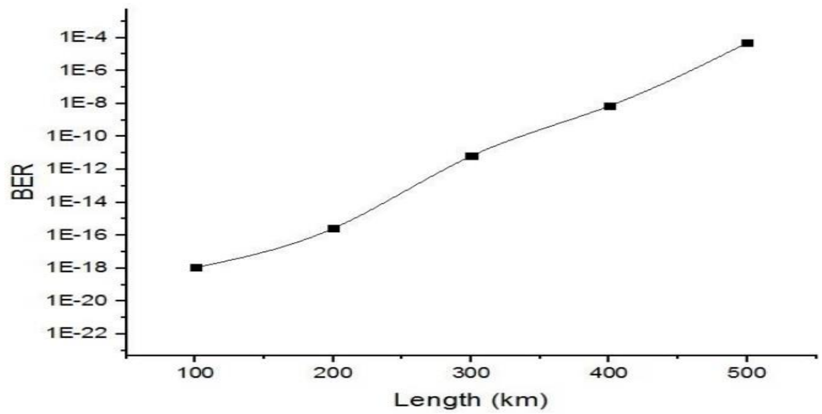

Fig. 8: *Length of optical fiber against BER*

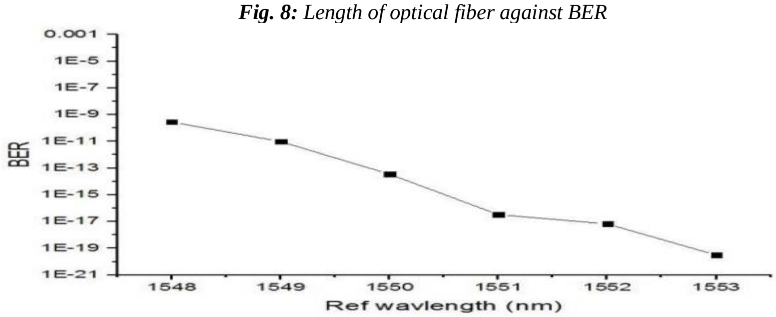

Fig. 9: *Ref wavelength against BER*.

So, from the results it is shown that system has fruit full performance till 500 km of path. Above 500 km of length system will not balance anymore. The results of reference wavelength against BER are mentioned in figure 9, which declares that nonlinearities at high distance can be treated at 1553 nm reference wavelength. Except 1553 nm wavelength proposed system gives failure results to treat nonlinearities. For calculating and displaying electrical signals in the frequency domain RF spectrum visualizer is utilized. It can show the power spectral density, signal intensity, and phase as given in Fig. 10. and Fig. 11. below for different values.

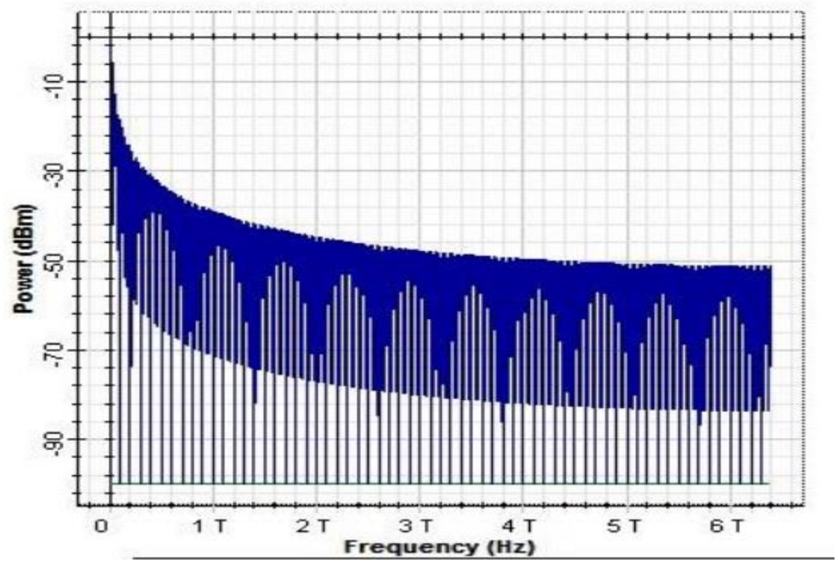

Fig. 10 *Multiple signal type display at 10-16 BER.*

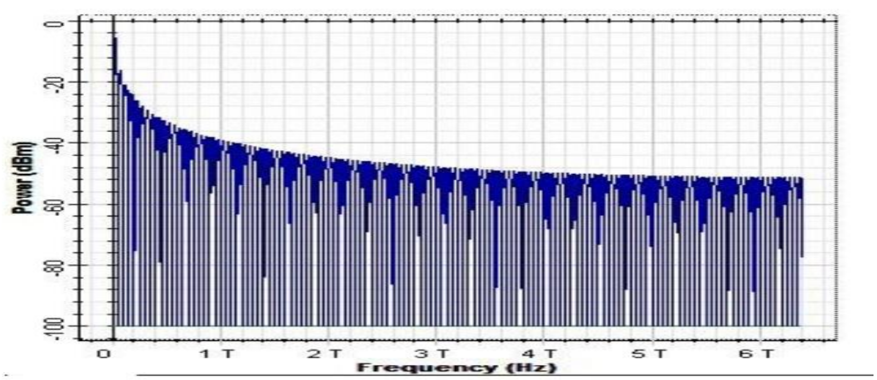

Fig. 11: *RF spectrum analyzer of different signals at 10-16 BER.*

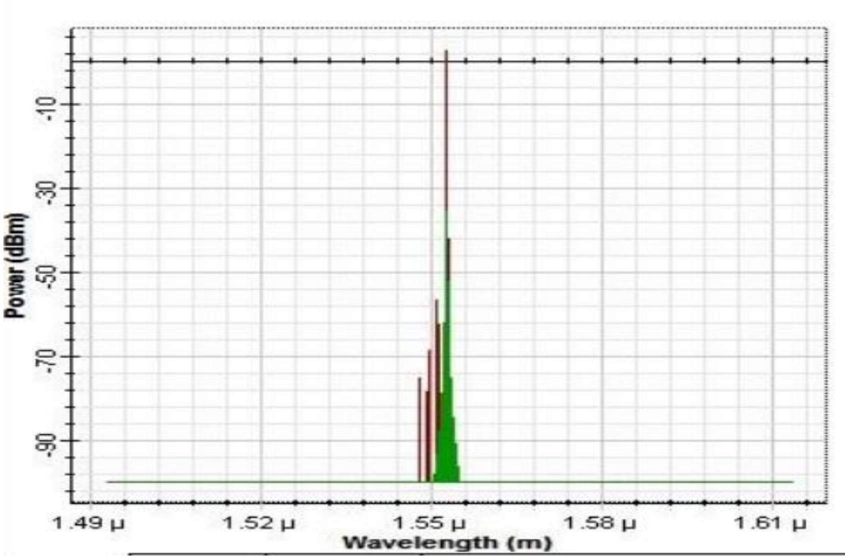

Fig. 12: *Optical spectrum analyzer at 10-16 BER*

The optical spectrum visualizer use to count on and show optical signals in the frequency domain. It can show the power spectral density, phase, group delay, signal intensity and dispersion for polarizations X and Y, as show in Fig. 12. for long haul communication system. BER analyzer diagram is presented in figure 13 and explained the system achievements against nonlinearities for long-haul high capacity optical networks.

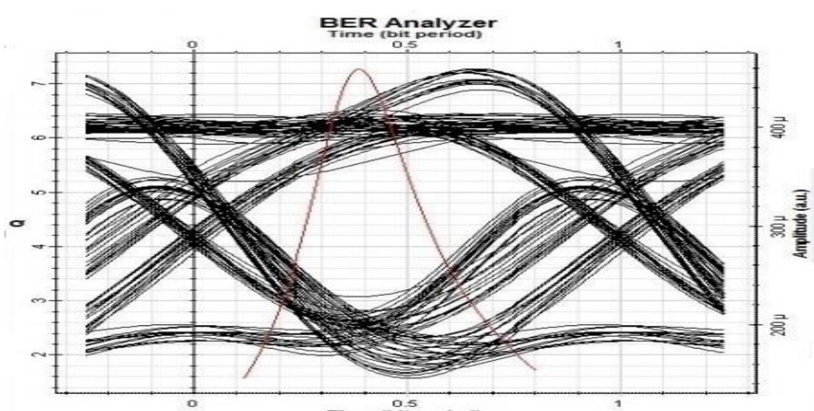

Fig. 13 BER analyzer eye diagram of the proposed work

Conclusion

The main purpose of this work was to design an optical network system that could transmit data up to high distance as much as possible including high order nonlinear issues. In this paper 4 ×100 Gbps data rate over a optical fiber WDM wide haul and high data rate system has been experimentally analyzed for which 1.56×10-16 BER is recorded. The proposed system was designed for four channels consist of 100 Gbps each hence becomes 400 Gbps for all four channel, with addition 200 GHz spacing between each channel. It is concluded from graphical and stimulation analysis that the proposed system is more reliable for high data rate. It is concluded that the projected system is very reliable and efficient for high data rates. This can be practically used for more than 4 channels in a WDM optical fiber long-range communication system.

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