Analysis of High Data Rate (Beyond 100Gbps) Long Haul Optical Network Using Duo Binary Differential Quadrature Phase Shift Keying Modulation Technique

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Abstract

Long haul and cost effective optical communication networks having data rate of 100Gbps or beyond is emerging research area for researchers in the field of optical communication. This paper presents and explore an analysis of Wavelength Division Multiplexing (WDM) system in a long haul optical network at 16 x 100_Gbps using advance modulation format of Duo Binary Differential Quadrature Phase Shift Keying (DQPSK) with channel spacing of 200GHz using 194.1THz signal. Significant results of low Bit Error Rate (BER) and High-Quality Factor (Q-factor) over 400Km of standard single mode fiber shows the feasibility of the proposed system for high data rate long haul optical networks.

Keywords: Wavelength Division Multiplexing; Duo Binary; Optical Networks; Signals; Data

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INTRODUCTION

The goal of long-haul optical fiber system is to transmit the high data throughput over long distances without the need for signal regeneration (Agarwal, 2005). Highly advanced modulation techniques gained importance due to the fact that these might provide tolerance to the impairments in optical networks (Tiwari et al., 2013). Optical systems designed for ultra-high data rates around 100Gbps face degradation due to effects of dispersion (Tiwari et al., 2013; Rasheed and Abdullah, 2014). For data rates beyond 100Gbps, dispersion is the limiting factor. Multilevel modulation techniques such as DQPSK have advantages like high spectral efficiency and improved tolerance to dispersion effects in optical fiber. DQPSK is extension to the differential four phases (0, a/2, b/2, c/2, d/2) keying principles (Tiwari et al., 2013; Kumar, 2016; Napoli et al., 2014).

In QPSK each symbol carries two bits. Therefore, for a bit rate of x, theoretical bandwidth required for transmission without inter symbol interference (ISI) is x/4Hz, resulting in decrease in bandwidth requirements and decreased effect of dispersion (Napoli et al., 2014; Liga et al., 2014). However, these research works have complex build up, less security and cost restrictions. To overcome these limitations, a cost effective set up and easy network structure for long haul high data rate system has been worked out. On the other hand DQPSK structure is less complex and offers photo detectors at receiving end which is very cost effective as compared to QPSK modulation format. Moreover, high advanced modulation format DQPSK is very fruitful for high speed transmission capability beyond 100_Gbps data rate, against chromatic dispersion and polarization mode dispersion (PMD) (Clausen et al., 2018; Pinto et al., 2016). This paper presents and explore an analysis of Wavelength Division Multiplexing (WDM) system in a long haul Optical network at 16 x 100_Gbps using advanced modulation format of Duo Binary Differential Quadrature Phase Shift Keying (DQPSK) with channel spacing of 200GHz using 194.1THz signal. Significant results of low BER and High-Quality Factor over 400Km of standard single mode fiber shows the feasibility of the proposed system for high date rate long haul optical networks. The rest of the paper is organized as, Section II will present analytical Model and Network Architecture while section III will cover the Simulation results, discussion and conclusion of the paper.

MATERIALS AND METHODS

Analytical Model

In this section the basic mathematics of the proposed work has been discussed for over 400_Gbps optical fiber communication network system with nonlinear issues Duo Binary Differential Quadrature Phase Shift Keying (DQPSK).

Transmitted signal of WDM system of the proposed network can be calculated using equation as

$$x(t) = \sum_{l=-\infty}^{\infty} d_l q(t - lT) \tag{1}$$

Here d_l means data bits, q (t) represents transmitted pulse and T is bit per period and equal to 1/f.

The output of the laser source is given by (Tiwari et al., 2013).

$$F_o = F_i e^{j\omega ct} \tag{2}$$

The optical fields are modulated using medium induced pulses, explained below as (Secondini and Forestieri, 2014).

$$E_o = \frac{E_i}{2}\left[e^{\frac{i\pi v1(t)}{v\pi}} + \gamma\, e^{\frac{i\pi v2(t) + v_{bias}}{v\pi}} \right] \tag{3}$$

The V_1 and V_2 are given as

$$V_1 = -V_2 = \frac{P(t)}{2} \tag{4}$$

The elements used in the above equations are input optical field denoted by E_i. V shows the magnitude of the modulator, γ is coefficient of the refractive index, and bias of the modulator circuit explored by V_{ibes}, V1 and V_2 explain the electrical pulses voltage.

The induced polarization by electric dipoles is given by (Zhou and Nelson, 2012).

$$p = \varepsilon_0 \,(x^n E_n!) \tag{5}$$

The parameter is permittivity of free space and equal to 8.85 x 10^{-12}F/m, x^n explains order of susceptibility where n is equal to 1, 2, 3…… The final element E_n denotes electric field. Initial term of the nonlinearity starts from x^3 called third order susceptibility, defines the direct nature of both the nonlinearity and order of susceptibility.

Network Architecture

Table 1 below shows the values of different parameters used in simulation for the proposed network.

Table 1: Simulation parameters

Parameter	Size and description	Parameter	Size and description
Input power	6dBm	Bit rate	1600Gbps
Number of channels	16	Sine generator	128GHz
Frequency spacing	200GHz	Pulse Generator	NRZ
Li MZM	20 dB extinction ratio	DWDM MUX	128GHz sample rate
Ref. wavelength	1550.5nm	Nonlinear Ref Index	$2.6*10^{-17}$
Length	400km	EDDFA	7m
Attenuation	0.2dB/km	Dispersion	17ps/nm
Beta2	$-18ps^2/km$	Beta3	$-3ps^3/km$
Nonlinear Effective area	$80\ um^2$	Linear Dispersion	0.075ps/nm
Nonlinear dispersion	$20\ ps/km/nm^2$		

The proposed architecture of the long haul high capacity optical network is shown in Figure 1.

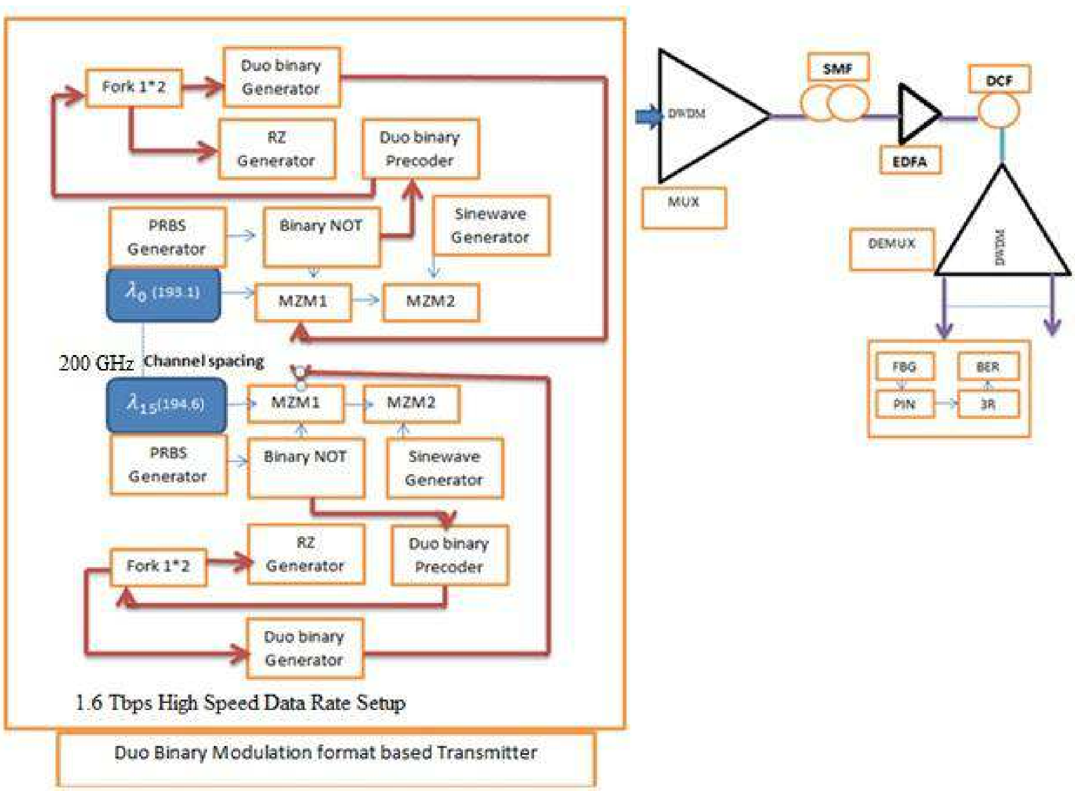

Figure 1: Network Architecture of the proposed system

In the above table some of the mentioned parameters are kept constant while others are varied such as nonlinear refractive index, nonlinear effective area, reference wavelength, linear and nonlinear dispersion and dispersion slope. Best results are achieved at 1550.5nm reference wavelength, 2.6 x 10^{-28} refractive index, and 80 um^2 effective area of the fiber for long haul optical communication system.

RESULTS AND DISCUSSION

Simulations Results

The simulation results are measured by using Opti-System software. In addition, the calculated results are drawn by Origin software. The simulation model used in Opti-System is shown as Figure 2.

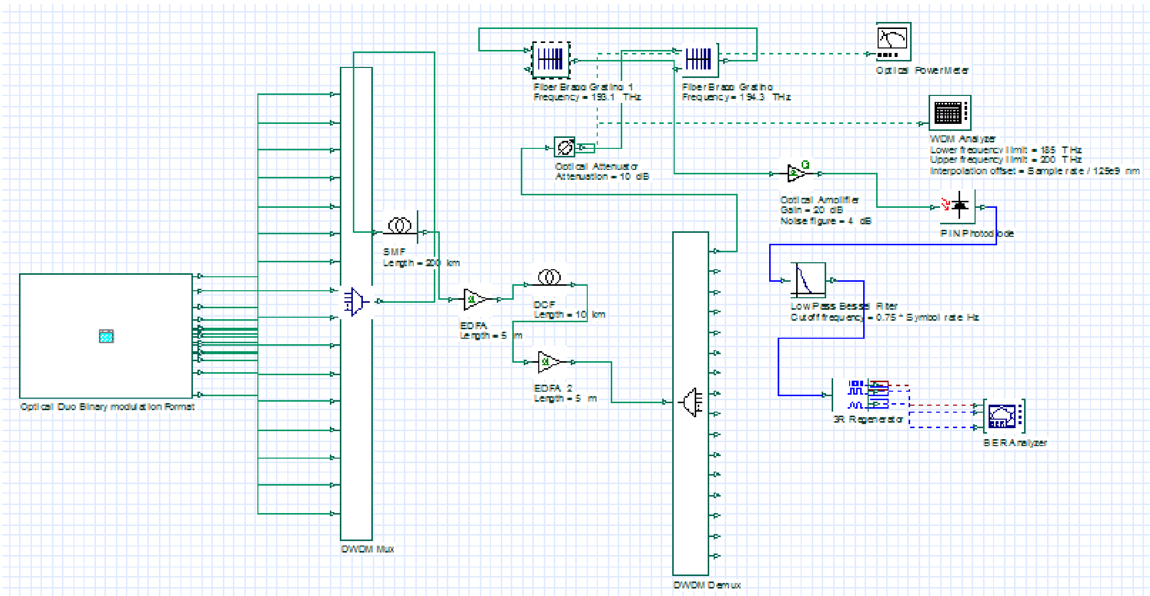

Figure 2: Simulation model of the proposed Network

Figure 3 shows the results based on different values of length of fiber-optic against BER. Clearly the proposed work has high performance at 100km and performance of the system decreases as the covered path increases.

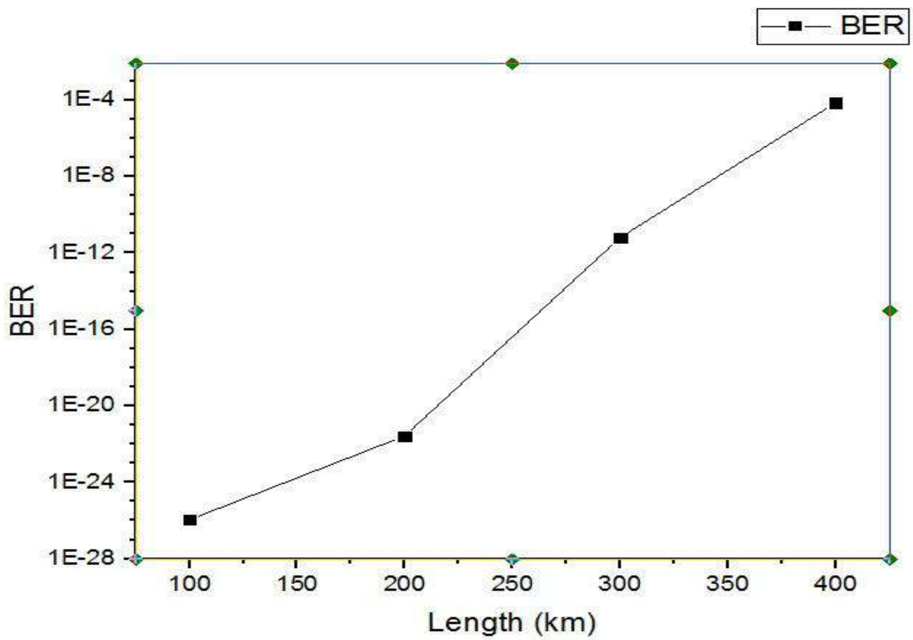

Figure 3: Proposed system performance in terms of Length and BER

Figure 4 shows Optical Signal to Noise Ratio (OSNR) verses length of optical fiber. The system has high signal to noise ratio at lower distance and less OSNR when length is increased.

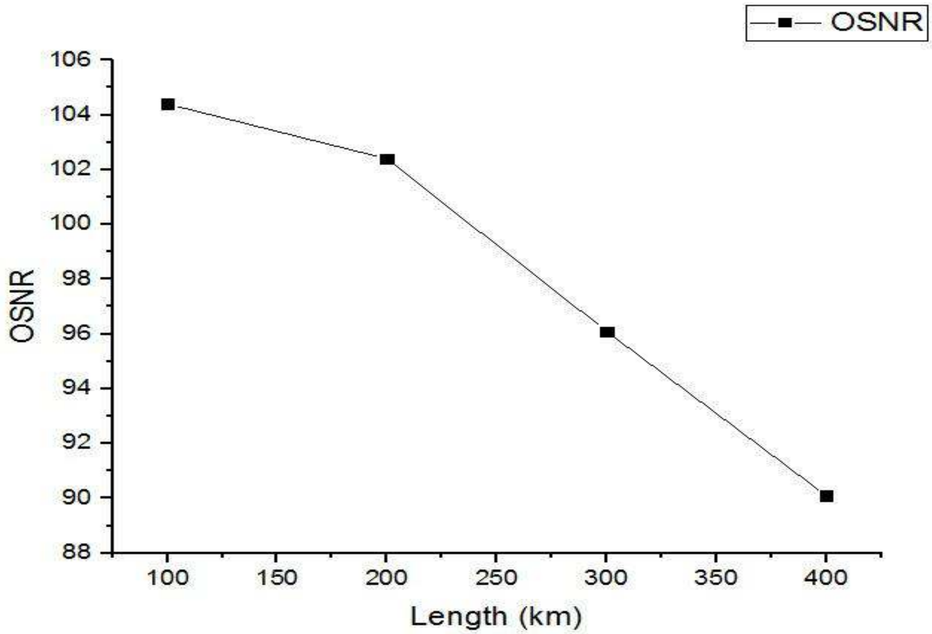

Figure 4: Graphical representation of proposed work in terms of Length and OSNR

Q-factor results as function of the length of the optical fiber is presented in Figure 5. Better result is analyzed at 10.6 quality factor.

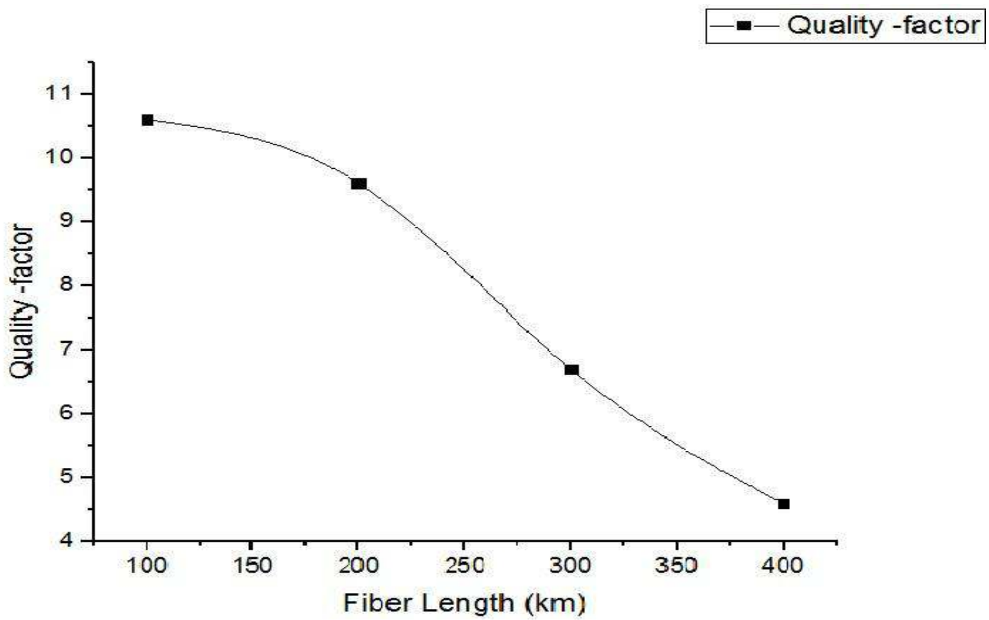

Figure 5: Graph among fiber-length and Q-factor

The received optical power and OSNR results of the proposed system are analyzed in Figure 6. Clearly, the system has satisfactory performance.

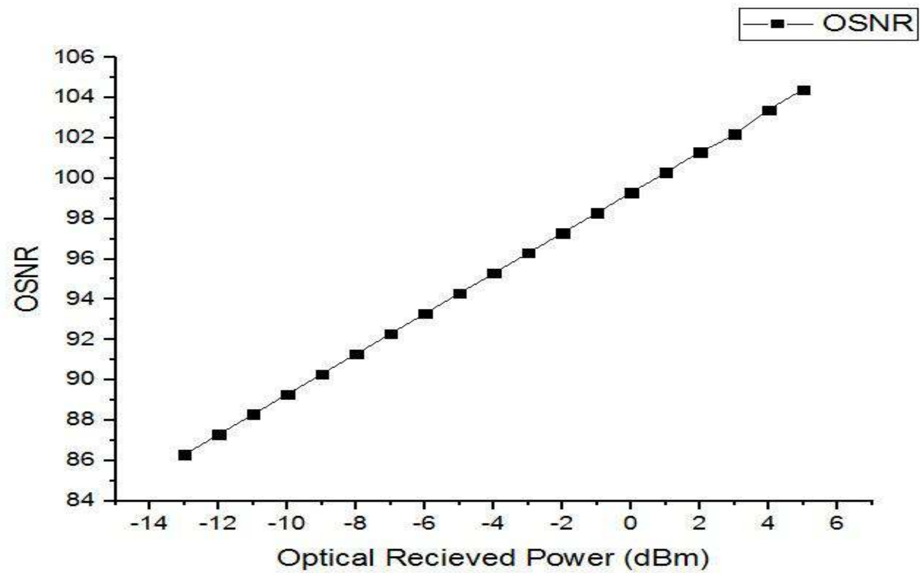

Figure 6: Results between OSNR against Received power

Figure 7 below shows reference wavelength and BER analyses. Graph shows that proposed optical network system gives efficient performance at 1550.5nm only.

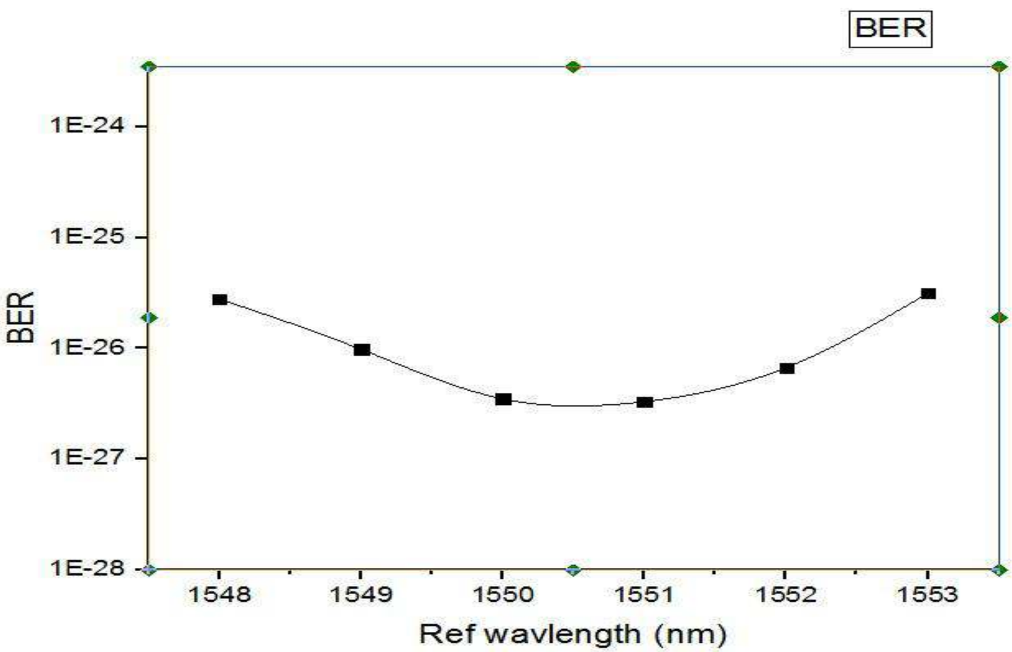

Figure 7: Graphical analysis of reference wavelength and BER

Figure 8 shows represents relationship between optical received power and BER. High data rate system performance increases from -15 to 10 dBm received power.

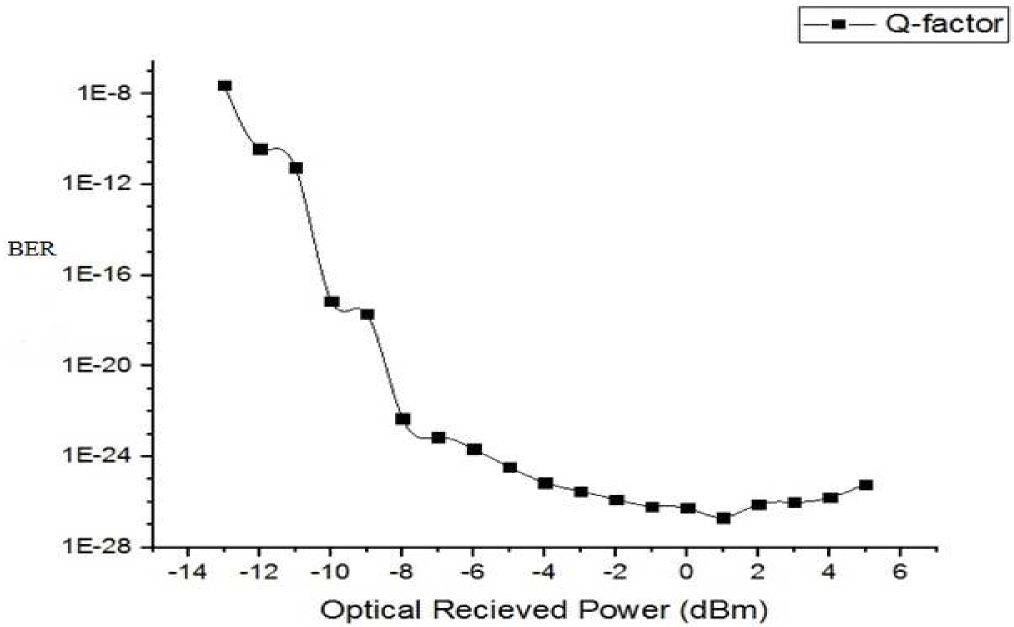

Figure 8: Optical received power vs BER of the long-haul and high data rate system

Graphical results between Q-factor and reference wavelength are given in Figure 9, which shows that high Q-factor is achieved at 1550.5-nm for optical fiber long distance communication.

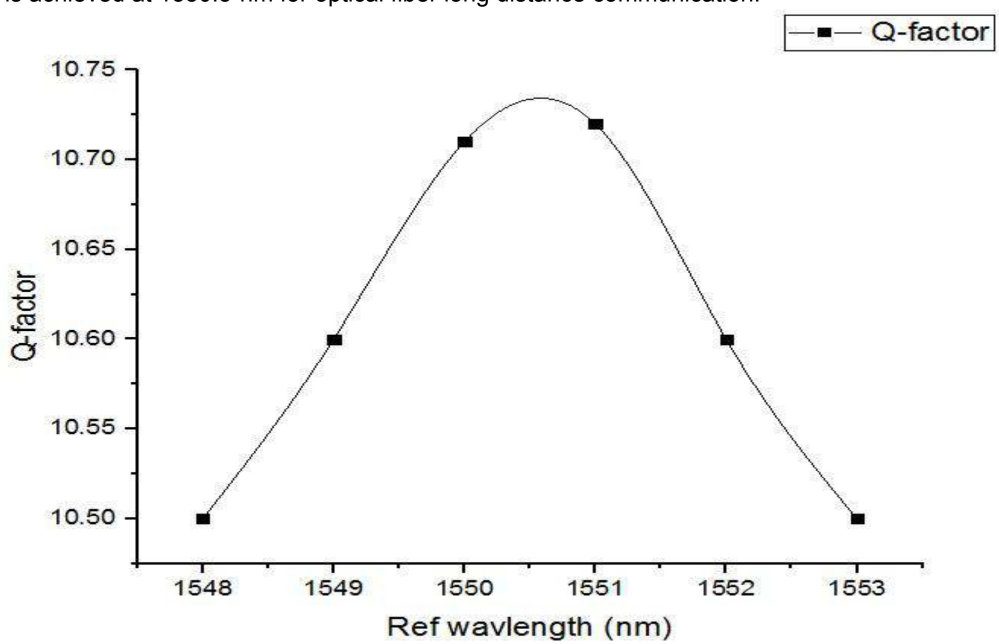

Figure 9: Reference wavelength against Q-factor

CONCLUSION

This paper has explored and analyzed the performance analysis of Wavelength Division Multiplexing (WDM) system in a long haul Optical Network at 16 x 100_Gbps using advanced modulation format of Duo Binary Differential Quadrature Phase Shift Keying (DQPSK) with channel spacing of 200GHz using 194.1THz signal. Significant results of low BER and High Quality Factor and High OSNR over 400Km of standard single mode fiber support the feasibility of the proposed system for high date rate long haul optical networks. From simulation results and graphical analysis, it is concluded that the proposed system is reliable and cost effective for high data rates which can practically be used in future WDM long haul optical communication systems.

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