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Performance analysis of OADM based DWDM System

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Abstract: The Dense Wavelength Division Multiplexing (DWDM) system based on Optical Add-Drop Multiplexer (OADM) is presented. The effect of Loss on Q factor and BER for different fiber lengths is analyzed. Also the effect of Bit Error rate (BER) with Channel Spacing and Data Rates for different channels is analyzed. The NRZ modulation format is used for the transmitting the signal for WDM system based on 4OADM.
Keywords: DWDM, OADM, BER, Q factor, Channel Spacing.

I. INTRODUCTION

In wavelength division multiplexing (WDM) systems, the nonlinear impairments such as cross-phase modulation (XPM) and four wave mixing (FWM) arising, which degrade the performance of the system. With the use of dispersion management these types of effects can be removed [1]. The compensation schemes have been expressed to suppress the non-linear effects. To suppress the non-linear impairments like as XPM and FWM in fiber, the capacity of WDM systems has been increased [2]. A theoretical model that allowed the impact of optical crosstalk to be assessed has been proposed and validated via experiments. The simulated results found that the power penalty is smaller for the higher speed system and the power penalty due to optical crosstalk is larger when the received background light power is smaller [3]. To increase the transmission capacity of wavelength division multiplexing system, there is the necessity the bit rate per channel and reduce the channel spacing [4]. The significant dispersion compensation for the systems, the conventional single-mode fiber (SMF) is required which is operated at high speed (>10 GB/s) [5]. A short-period dispersion-managed fiber has been proposed to suppress both chromatic dispersion and fiber nonlinearities simultaneously. This fiber consists of short positive and negative dispersion fibers within a single cable [6]. The length and dispersion of both fibers should be designed properly to minimize the influence of FWM. The ratio of the generated FWM power to the transmitted signal power is a function of section length [7]. The quality of the transmission of each channel for a Wavelength Division Multiplexed (WDM) system with a 640 GB/s data rate (16 x 40 GB/s) with RZ modulation for different channel spacing is examined. There are many optical signals sent by transmitters, which is in the form of lasers, are coupled together into a fiber using a multiplexer [8]. Signal attenuation is compensated using amplifiers such as erbium-doped fiber amplifiers (EDFAs). The performance of 10 Gbps optical communication system with the dispersion managed the return-to-zero (RZ) pulse is efficient for long-distance, high-bit-rate, wavelength division multiplexed (WDM) transmission dispersion-managed systems [9]. With the variation of dispersion parameter of single mode fiber, it has been observed that with increase in the value of dispersion parameter, there is an increase in the average eye opening and Q-factor value [10]. With the comparison of RZ and NRZ modulation format, it is found that NRZ is more affected by nonlinearities, whereas RZ is affected by dispersion. In the dispersion map, 10- and 20-Gb/s systems operate better using RZ modulation format because nonlinearity dominates [11]. Dispersion management is a technique which suppresses the nonlinear effects and it also utilized utilizing single-mode fiber (SMF) and dispersion compensating fiber (DCF). Dispersion compensating fiber (DCF) has been reduced the four wave mixing [12]. To analyze the performance of the system for NRZ, RZ and Duo binary modulation format, it is observed that the Duo binary and RZ modulation format is best for the long distances at high bit rates whereas NRZ modulation format is best for the small communication system at high bit rates [13]. NRZ is the simplest configuration of transmitter and receiver and it requires a relatively low electrical bandwidth for transmitter and receivers compare with the RZ and its pulses have a narrow optical spectrum. With the reduced spectrum width improves the dispersion tolerance; it has the effect of inter symbol interference. The RZ pulse shape enables an increased robustness to fiber nonlinear effects and to the effect of polarization mode dispersion (PMD) [14]. In WDM channels, with using higher order modulation formats spectral efficiency has been increased. To increased the optical signal-to-noise ratio (OSNR) for increasing the transmission distance [15]. The optical cross add and drop multiplexing (OXADM) is new device which is invented to improve the limitations and impairments which appeared in the coarse wavelength division multiplexing (CWDM) system which is designed with the combination of optical cross connect (OXC) and optical add and drop multiplexing OADM. OXADM systems consist of elements which provided the capability to connecting the traffic in OADM and OXC network [16]. In WDM systems, the optical add-drop multiplexer (OADM)

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is used to improve the bandwidth efficiency through reconfigures the network [17]. It has achieved good results within MIMO-OFDM system with OADM recently for optical-OFDM system and Monitoring and Compensation of Optical Telecommunication Channels [18].

II. SYSTEM SETUP

Wavelength division multiplexing, which is used multiple channels to transmit a multiple signals over a single optical fiber, is designed in a Fig.1. Increasing the capacity of optical systems may require an increase in the bit rate, usage of WDM. Externally Modulated Subsystem simplifies the entire design process. From the beginning, the number of output ports should be entered, and then start inputting the Frequency values for each channel. The frequency values can be entered individually. An ideal Erbium Doped Fiber Amplifier is used, which is concerned with the values of Gain and Noise Figure. In this section, we design a 16-channel 40 Gb/s DWDM transmission system. The 16 x 40 Gb/s DWDM transmission system as designed is shown in Fig. 1. It consists of transmitter section, link section, 4 channel OADM and receiver section.

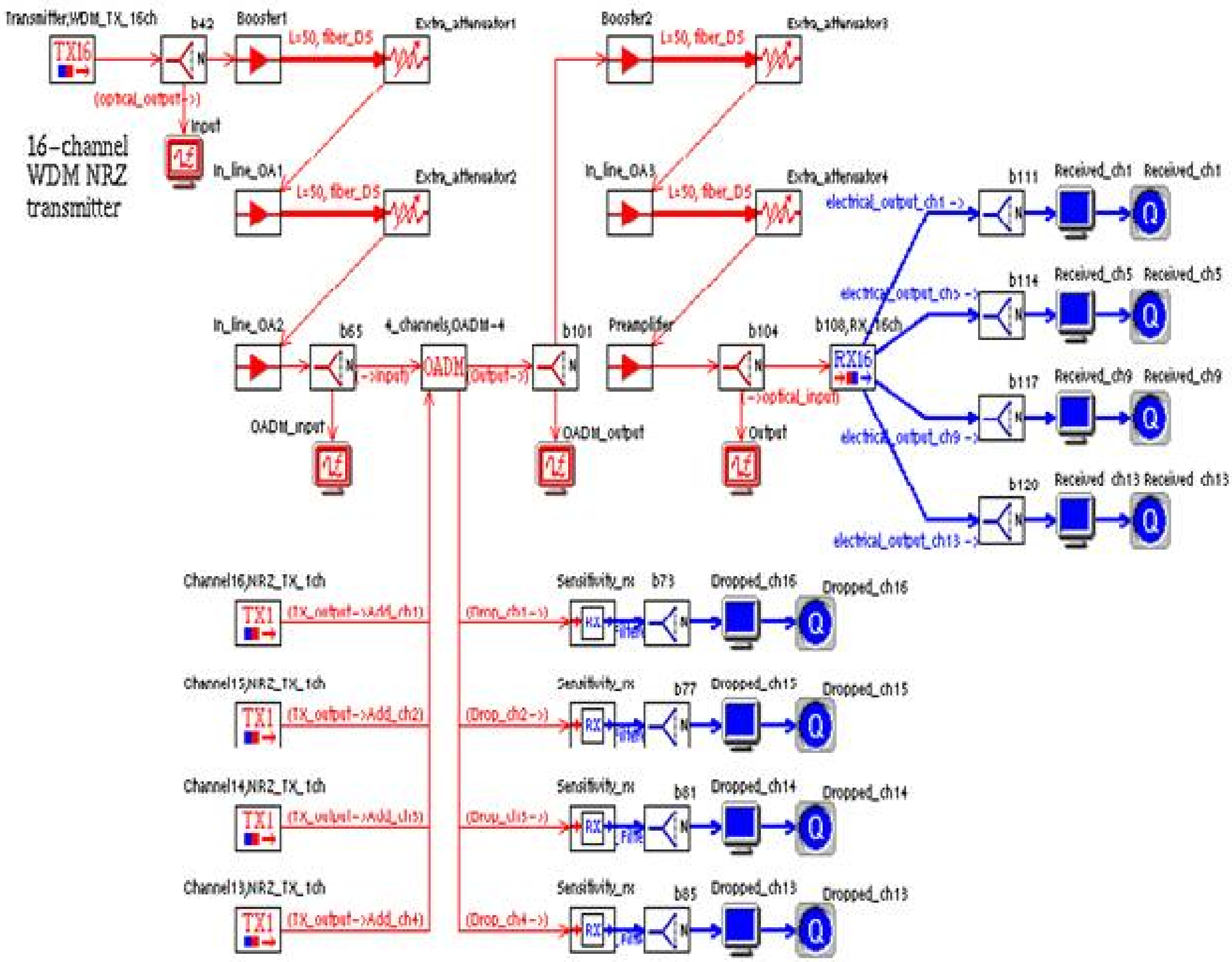
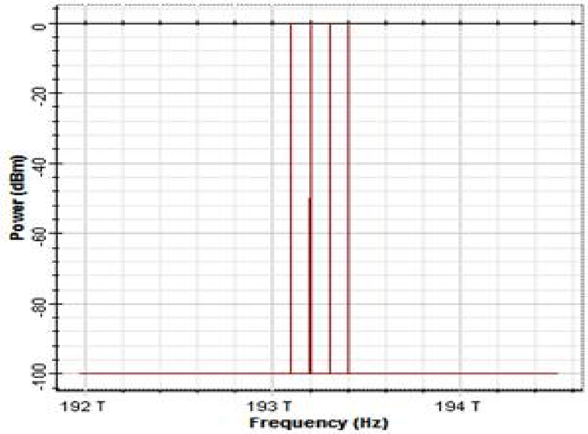


Fig. 1: 40 GB/s, 16 Channel WDM System

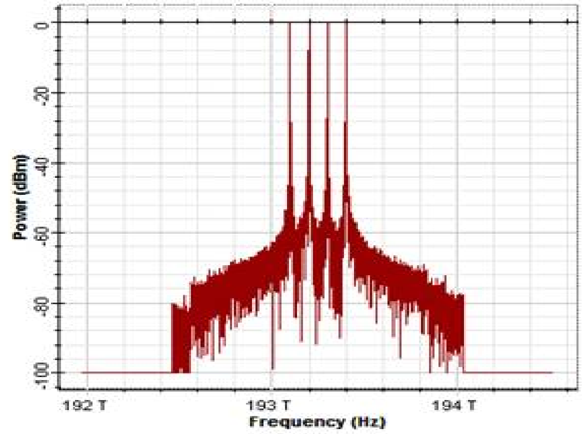
III. RESULTS & DISCUSSIONS

A. Analysis of Effect of Loss on Q Factor and BER

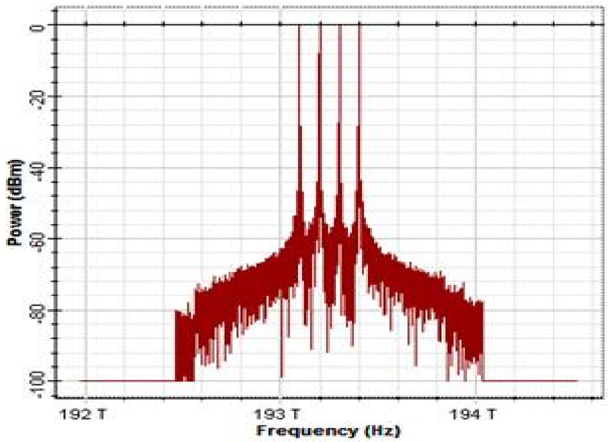
The effect of Loss on Q factor and BER for different fiber lengths is analyzed. In the first phase the performance of OADM is analyzed by transmitting data from four independent channels and individual channel is added and dropped one by one. Depending on the performance at different wavelength by observing optical spectrum successful reception of signal is observed as shown in Figure 2.



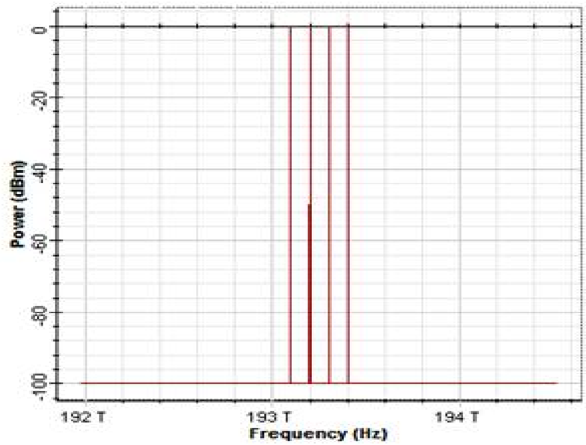
a) Input



b) Add



c) Drop



d) Output

Figure 2: OADM Performance

Optical power meters are also inserted to check the power level measurement at transmitter and receiver side as shown in Figure 3.

Figure 3 (a): Power measurement at Transmitter

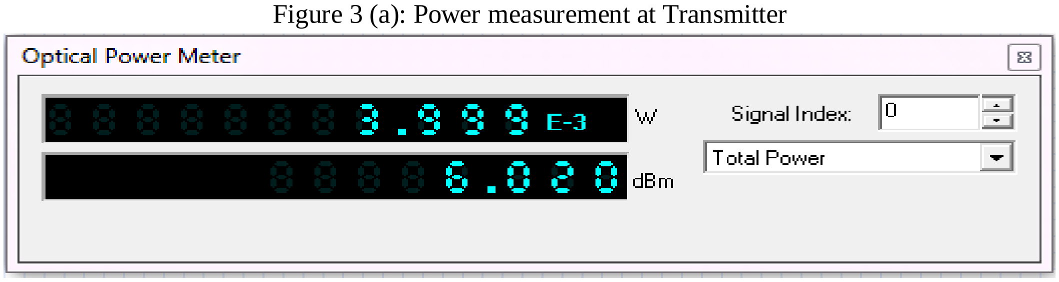


Figure 3 (b): Power measurement at Receiver

The results are examined with different length on optical fiber links and loss. The effect of loss on Q factor and BER with different

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lengths is analyzed. The Q Factor and BER are varied with variation in the length.

Table 1: Variation of BER and Q factor with Loss for Different Lengths

Length	80km		200km		280km	
Loss dB/km	Q Factor	BER	Q Factor	BER	Q Factor	BER
0.10	20.7608 (db)	1.18621e-027	14.0043 (db)	3.647e-007	10.5152 (db)	0.000435189
0.15	19.9907 (db)	1.1062e-023	14.1223 (db)	1.796e-007	10.2611 (db)	0.00056028
0.20	20.7932 (db)	2.2579e-028	15.4924 (db)	2.484e-009	10.1696 (db)	0.000778691
0.25	18.9432 (db)	2.07993e-018	14.0030 (db)	2.561e-007	10.2812 (db)	0.000217322

Table 1 discusses about the effect of loss on Q factor and BER with different optical fiber lengths. The loss is varied at the 0.10dB, 0.15dB, 0.20dB and 0.25 dB. The values of Q factor and BER have been taken at length 80km, 200km and 280km.

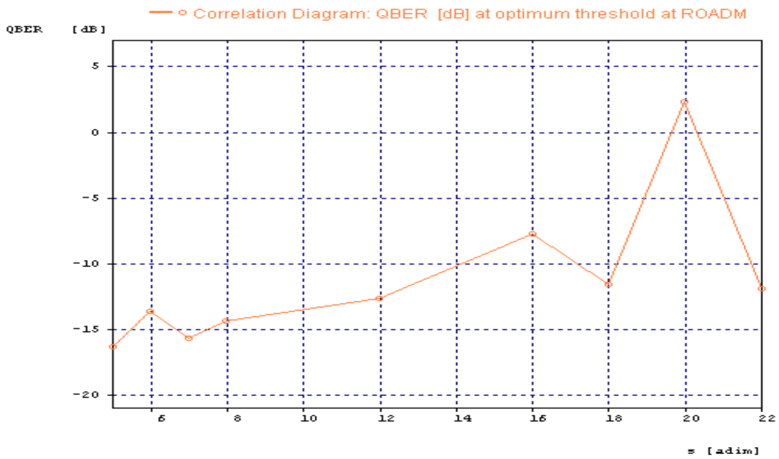

Figure 4: Performance analysis at different data rates and samples

Layout of DQPSK receiver is also explicitly simulated in order to obtain the in-phase (Eye_P) and Quadrature (Eye_Q) eye diagrams each having data rate of 20 Gbps and in total data transmitted rate is 40 Gbps and with different samples combinations varying from 4 to 22. Results showed in Fig. 4 explain the acceptable data rate of 40 Gbps with 20 samples. Power spectrum at the OADM input with different filter types is as shown in Fig. 5.

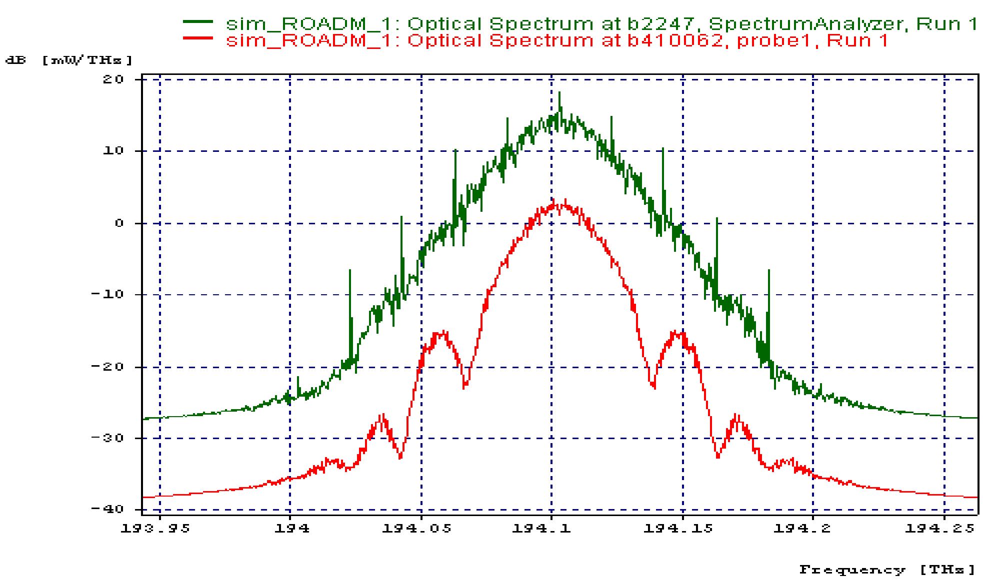

Figure 5: Power spectrum at ROADM

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B. Analysis of Effect of BER with Channel Spacing and Data Rates for DWDM System

Bit error rate (BER) is the ratio between the number of bits received in error to the total number of bits received. In essence, BER is the probability of receiving a single bit in error. From the various results obtained the BER trend is studied for optimization.

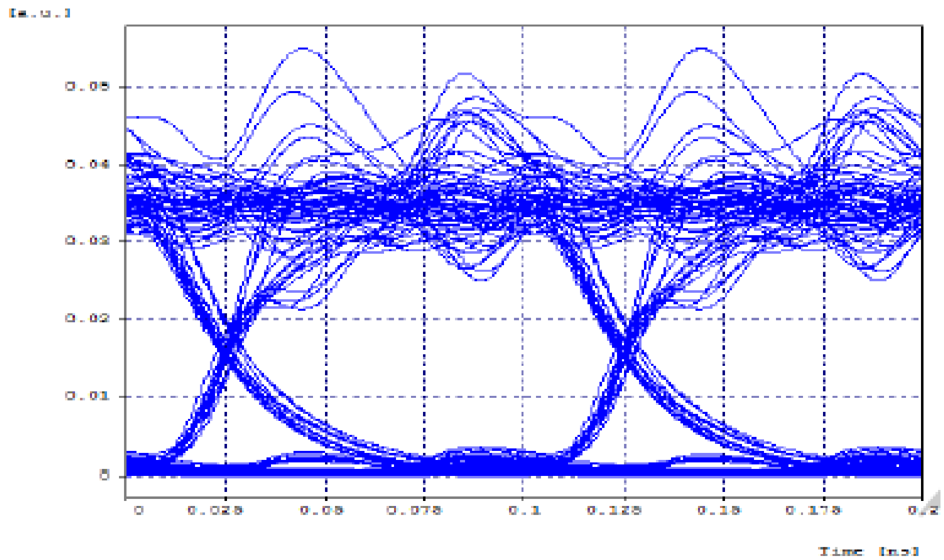

Figure 6: Eye diagram for 30GHz, 10 Gb/s DWDM system

Fig. 6 shows the eye pattern obtained for a 16 channels DWDM system with the data rate of 10 Gb/s and channel spacing of 30 GHz having BER of 3.24e-003. The output of the system was analyzed in terms of BER by changing the number of channels from 16 to 32 and 64 channels. The analysis indicates that BER increases with number of channels.

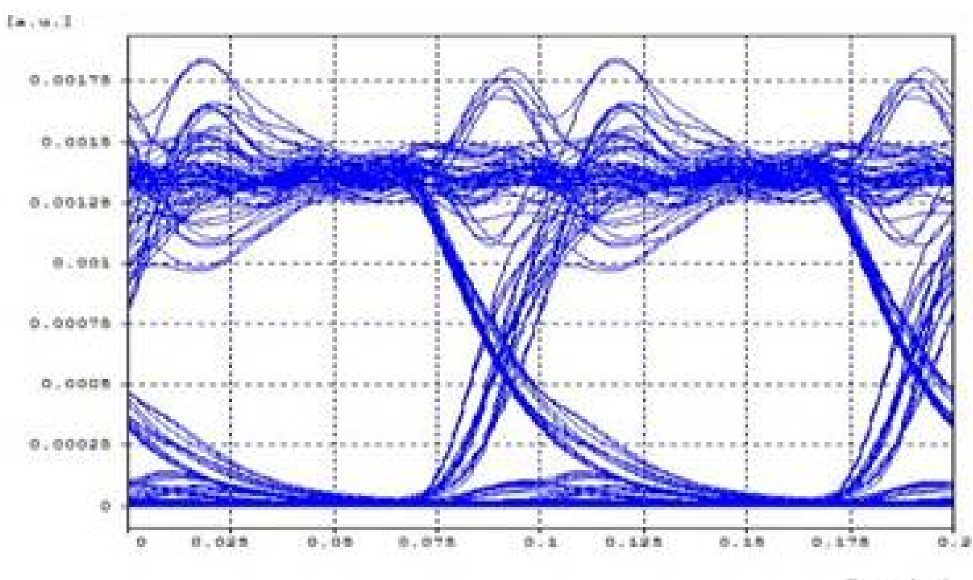

Figure 7: Eye diagram for 50GHz, 10 Gb/s DWDM system

Fig. 7 shows the eye diagram obtained for a 16 channels DWDM system having 50 GHz channel spacing and a data rate of 10 GB/s. A typical value of BER obtained is 1.08e-029. The output of the system was analyzed in terms of BER by changing the number of channels from 16 to 32 and 64 channels. Comparing with Fig. 6 it is observed that BER becomes very small when we increase the channel spacing from 30 to 50 GHz.

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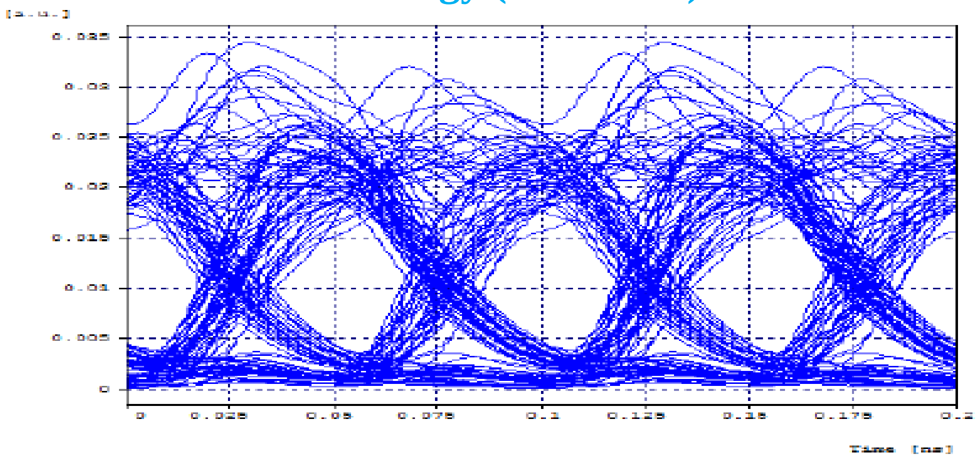

Figure 8: Eye diagram for 30GHz, 20 Gb/s DWDM system

Fig. 8 shows the eye pattern obtained for a 16 channels DWDM system with the data rate of 20 Gb/s and channel spacing of 30 GHz having BER of 1.12e-002. The output of the system was analyzed in terms of BER by changing the number of channels from 16 to 32 and 64 channels. As compared to Fig. 7 it is observed that as the data rate is increased from 10 to 20 Gb/s, BER also increases.

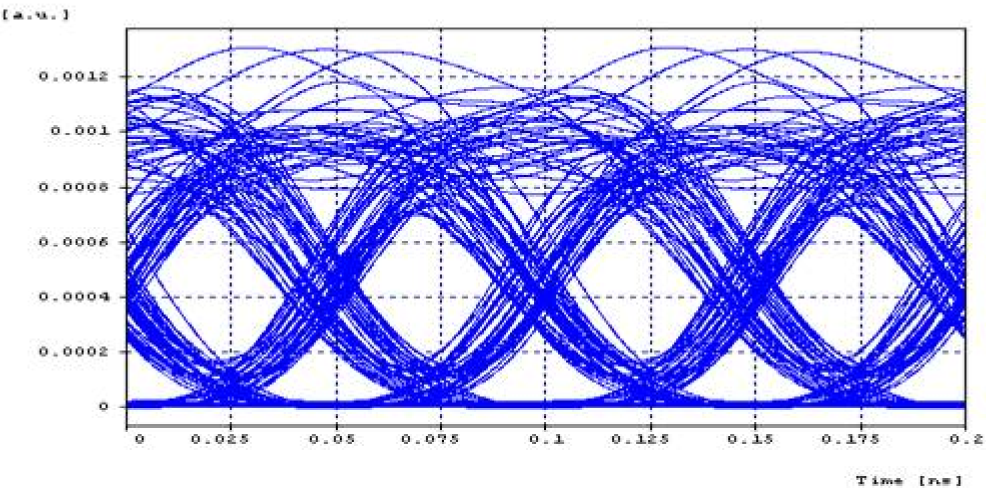

Figure 9: Eye diagram for 50GHz, 20 Gb/s DWDM system

Fig. 9 shows the eye diagram obtained for a 16 channels DWDM system having 50 GHz channel spacing and a data rate of 20 GB/s. A typical value of BER obtained is 1.58e-025. The output of the system was analyzed in terms of BER by changing the number of channels from 16 to 32 and 64 channels. Comparing with Fig. 8, it is observed that BER becomes very small when we increase the channel spacing from 30 to 50 GHz. All the results of BER obtained from different setups are summarized in Table 2 below:

Table 2: BER trends for DWDM System with different data Rates and Channel Spacing

Data Rates Gb/s	30 GHz Channel Spacing			50 GHz Channel Spacing		
	16 Channels	32 Channels	64 Channels	16 Channels	32 Channels	64 Channels
10 Gb/s	3.24e-003	4.43e-003	5.53e-003	1.08e-029	3.32e-027	9.35e-011
20 Gb/s	1.12e-002	7.88e-003	1.87e-002	1.58e-025	2.76e-018	1.85e-012

Table 2 represents the BER values obtained from the iterative analysis. The values are shown for all the three systems i.e. 16, 32 and 64 channels, which are analyzed for different data rates and channel spacing. From the iterative analysis carried out to obtain the system with optimized capacity, it was observed that for applications requiring high speed communication and more number of users like 64, a DWDM system with 50 GHz channel spacing proved to give better performance.

IV. CONCLUSIONS

The performance of the system has been analyzed over different lengths of fiber. The effect of loss on Q factor and BER for different optical links length is examined. The variation of BER and Q factor with loss is calculated at lengths 80km, 200km and 280km. The performance of the 16 channel WDM system based on OADM has been evaluated by varying loss and optical links length. Also the effect of Bit Error rate (BER) with Channel Spacing and Data Rates for different channels is analyzed. It has analyzed the value of Q factor decreases with the increases in length. The OADM system gives the lowest BER for the long transmission.

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