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Design and Performance Optimization of 8-Channel WDM System

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Abstract—This paper focuses on design of an 8-channel WDM System and then optimizing its performance parameters. This paper also focuses on evaluation of dependencies of various performance evaluating parameters onto various system parameters. Thus evaluating optimum fiber length, Channel frequencies and frequency spacing.This paper also draws an effective comparison between Non-EDFA WDM system and an EDFA based WDM system. The system was simulated and analyzed with OPTISYSTEM9 Simulation Tool.

Keywords—BER, EDFA Amplifiers, OSNR, WDM Dispersion, Wavelength Division Multiplexing

I. INTRODUCTION

In this digital era the communication demand has increased from previous eras due to introduction of new communication techniques. As we can see there is increase in clients day by day, so we need huge bandwidth and high speed networks to deliver good quality of service to clients. Fiber optics communication is one of the major communication systems in modern era, which meets up the above challenges. This utilizes different types of multiplexing techniques to maintain good quality of service without traffic, less complicated instruments with good utilization of available resources .Wavelength Division Multiplexing (WDM) is one of them with good efficiency. It is based on dynamic light-path allocation. Here we have to take into consideration the physical topology of the WDM network and the traffic. We have designed here an 8-channel WDM system and carried out detailed analysis to evaluate the dependencies of the performance evaluating parameters onto the various system parameters.

II. WDM

In optical communication, wavelength division multiplexing (WDM) is a technology which carries a number of optical carrier signals on a single fibre by using different wavelengths of laser light. This allows bidirectional communication over one standard fibre with in increased capacity. As optical network supports huge bandwidth; WDM network splits this into a number of small bandwidths optical channels. It allows multiple data stream to be transferred along a same fibre at the same time. A WDM system uses a number of multiplexers at the transmitter end, which multiplexes more than one optical signal onto a single fibre and de-multiplexers at the receiver to split them apart. Generally the transmitter consists of a laser and modulator. The light source generates an optical carrier signal at either fixed or a tuneable wavelength. The receiver consists of photodiode detector which converts an optical signal to electrical signal [1]. This new technology allows engineers to increase the capacity of network without laying more fibre. It has more security compared to other types of communication from tapping and also immune to crosstalk [2].

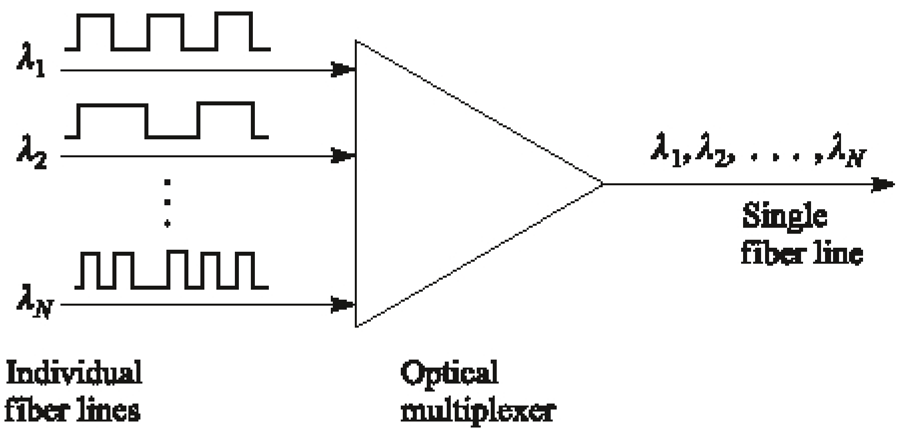

Fig. 1 Wavelength Division Multiplexing System

III. WDM TYPES OF NETWORKS

The optical network has huge bandwidth and capacity can be as high as 1000 times the entire RF spectrum. But this is not the case due to attenuation of signals, which is a function of its wavelength and some other fibre limitation factor like

imperfection and refractive index fluctuation. So 1300nm (0.32dB/km)-1550nm (0.2dB/km) window with low attenuation is generally used.
According to different wavelength pattern there are 3 existing types as:-
- WDM (Wavelength Channel Multiplexing)
- CWDM (Coarse Wavelength Division Multiplexing)
- DWDM (Dense Wavelength Division Multiplexing)

Table1 Types of WDM Networks

Parameter	WDM	CWDM	DWDM
Channel Spacing	1310nm & 1550nm	Large,1.6nm-25nm	Small,1.6nm or less
No of base bands used	C(1521-1560 nm)	S(1480-1520 nm)C(1521-1560 nm),L(1561-1620 nm)	C(1521-1560 nm),L(1561-1620 nm
Cost per Channel	Low	Low	High
No of Channels Delivered	2	17-18 most	hundreds of channel possible
Best application	PON	Short haul, Metro	Long Haul

III.WDM BENEFITS

Wavelength Channel Multiplexing (WDM) is important technology used in today's telecommunication systems. It has better features than other types of communication with client satisfaction. It has several benefits that make famous among clients such as:

A. Capacity Upgrade

Communication using optical fibre provides very large bandwidth. Here the carrier for the data stream is light. Generally a single light beam is used as the carries. But in WDM, lights having different wavelengths are multiplexed into a single optical fibre. So in the same fibre now more data is transmitted. This increases the capacity of the network considerably

B. **Transparency**

WDM networks supports data to be transmitted at different bit rates. It also supports a number of protocols. So there is not much constraint in how we want to send the data. So it can be used for various very high speed data transmission applications.

C. Wavelength Reuse

WDM networks allows for wavelength routing. So in different fibre links the same wavelength can be used again and again. This allows for wavelength reuse which in turn helps in increasing capacity [3].

D. Scalability

WDM networks are also very flexible in nature. As per requirement we can make changes to the network. Extra processing units can be added to both transmitter and receiver ends. By this infrastructure can redevelop to serve more number of people.

E. Reliability

WDM networks are extremely reliable and secure. Here chance of trapping the data and crosstalk is very low. It also can recover from network failure in a very efficient manner. There is provision for rerouting a path between a source destination node pair. So in case of link failure we will not lose any data [4].

IV.OPERATIONAL BLOCK DIAGRAM

The operational block diagram of a general WDM system is given below in Fig2

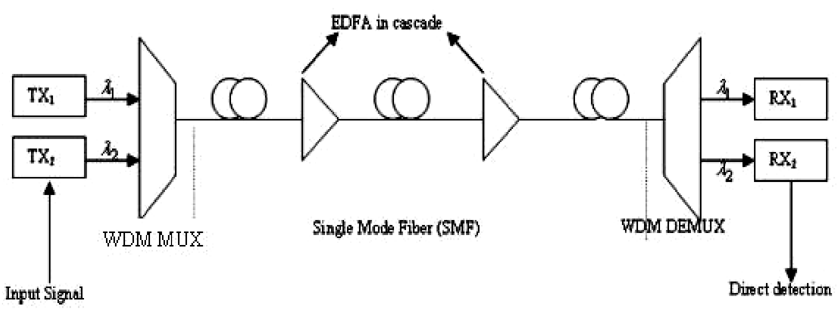

Fig. 2 Block Diagram of a general WDM System

Here input data (Digitized) generated at different wavelengths is given to the input of a WDM multiplexer which multiplexed them into a single data stream. This data after proper electro-opto conversion and external modulation is transmitted to the desired length via single mode optical fiber. Proper amplification is provided by deployment of looped EDFA amplifier with adequate gain. At reception the data streams are separated by WDM de-Mux and filtered to their respective wavelengths after proper opto-electro conversion.

V. **Performance Evaluating Parameters For Wdm System**

The various parameters which give us a measure of how good or bad the transmission is are called as Performance Evaluating parameters. The various Performance evaluating parameters are

Bit Error Rate (BER): In telecommunication transmission, the bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission, usually expressed as ten to a negative power.

Q-Factor: Physically speaking, Q is 2π times the ratio of the total energy stored divided by the energy lost in a single cycle or equivalently the ratio of the stored energy to the energy dissipated per one radian of the oscillation. Equivalently, it compares the frequency at which a system oscillates to the rate at which it dissipates its energy.

Eye Height: Eye diagrams show parametric information about the signal – effects deriving from physics such as system bandwidth health, etc. It will not show protocol or logical problems – if logic 1 is healthy on the eye, this does not reveal the fact that the system meant to send a zero. The height of such an eye diagram from bottom to top is called eye height and is a performance evaluation component, the larger the eye height the better is the transmission.

OSNR: Optical Signal to Noise Ratio (OSNR) is defined as the ratio of optical signal power to the noise power within the system. Higher the OSNR better is the signal reception.

VI. **System Parameters**

The various system parameters onto which the performance of the WDM system depends include Frequency Spacing between adjacent channels, Fiber Length, EDFA Gain and operating Frequency of channels.

VII. **Simulation Setup**

The system was simulated through optisystem9 simulator and the setup is shown in Fig3

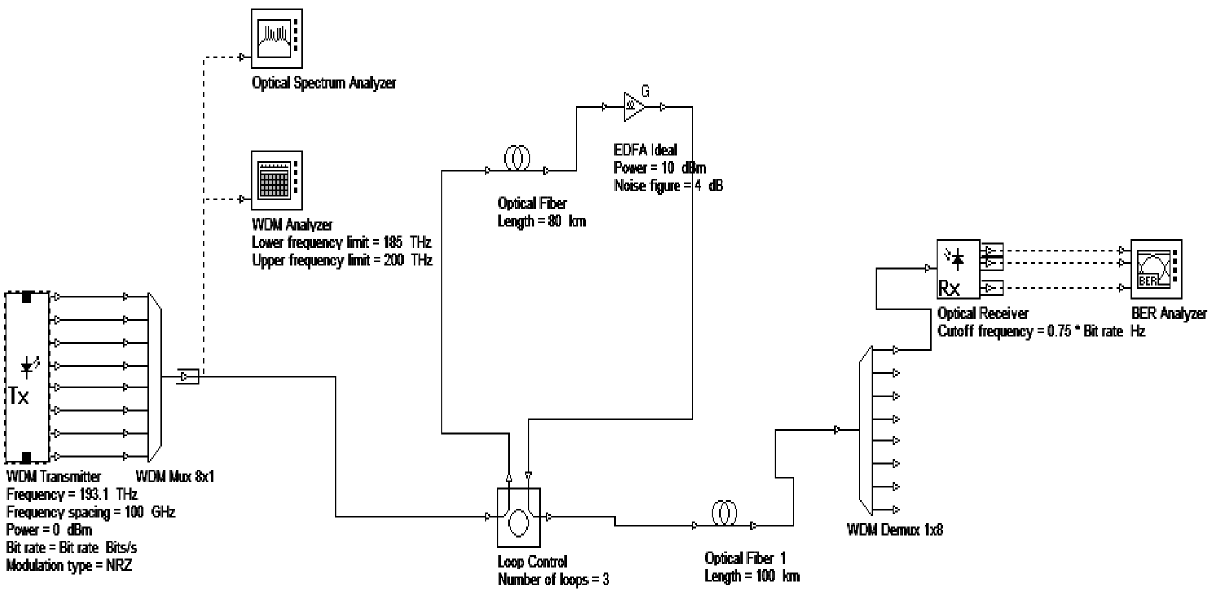

Fig. 3 Simulation Setup for an 8-Channel WDM System

Here Input data streams are generated through WDM Transmitter. This transmitter does the job of data generation, data sequencing, Electrical Modulation, Optical Conversion and External modulation using MZ Modulator. The eight data channels are then multiplexed in wavelength domain by an 8x1 WDM Multiplexer and then transmitted after proper amplification by looped EDFA amplifier through an optical fiber. At reception these data channels are separated in wavelength by an 1x8 WDM de-Multiplexer. All these data channels are then brought back to original form and format with optical Receivers deployed at back end. The quality of reception is checked by the BER Analyzers and various optical and electrical analysers.

VIII. INITIAL VALIDATION DATA

The initial validation data used for initial validation of the setup are as follows

Table2 Initial System Parameters

PARAMETERS	VALUE
Fiber Length	100 km
EDFA Gain	20dB
Laser Power	0 dB
Bit Rate	2.5×10^9
No. Of Loops	3
Sequence Length	128
Samples per Bit	64
No. of Samples	8192
Bessel Filter Cut-off Frequency	0.5× Bit rate Hz

Table 3 Initial Channel Frequencies

CHANNEL NO.	FREQUENCY (THz)	OSNR(dB)
01	193.1	72.97679
02	193.2	70.05075
03	193.3	70.068654
04	193.4	69.769986
05	193.5	70.216169
06	193.6	69.918133
07	193.7	69.853446
08	193.8	73.085746

Table4 Initial Perfromance Parameters

Channels	BER	Q Factor	Eye Height	Threshold
01	7.224411×10^{-10}	6.04979	1.33404×10^{-5}	1.29564×10^{-5}
02	1.84273×10^{-9}	5.89611	1.2005×10^{-5}	1.17396×10^{-5}
03	9.52138×10^{-10}	6.00381	1.25347×10^{-5}	1.19111×10^{-5}
04	6.04768×10^{-7}	4.84829	9.638×10^{-6}	1.08995×10^{-5}
05	2.91265×10^{-11}	6.54695	1.38547×10^{-5}	1.19668×10^{-5}
06	2.78824×10^{-9}	5.82539	1.24652×10^{-5}	1.07949×10^{-5}
07	1.63463×10^{-8}	5.52535	1.16027×10^{-5}	1.24412×10^{-5}
08	1.14705×10^{-10}	6.33826	1.33131×10^{-5}	1.10522×10^{-5}

IX.SIMULATION RESULTS

After the validation of design multiple simulations were carried out to evaluate the dependencies of various performance evaluating parameters onto the various system parameters .The data extracted has been shown in tabular form as follows

Table5 Channel1 Vs Fiber Length

Fiber Length(Km)	-Ve Log BER	Max.Q-Factor
5	223.56	31.9354
10	273.57	35.3564
15	276.85	35.5691
20	254.74	34.1097
25	234.99	32.7518
30	225.54	32.0821

35	195.43	29.846
40	176.73	28.3692
45	148.92	26.0191
50	157.63	26.7776
55	117.90	23.1199
60	104.48	21.7445
65	88.11	19.9438
70	66.82	17.3223
75	56.25	15.8619
80	37.85	12.9357
85	32.50	11.9525
90	22.86	9.94237
95	17.44	8.61226
100	11.59	6.90343
105	6.15	4.82599
110	5.65	4.59146
115	3.38	3.34766

TABLE6 CHANNEL2 VS FIBER LENGTH

Fiber Length(Km)	**-Ve Log BER**	**Max.Q-Factor**
5	280.08	35.7755
10	239.37	33.0544
15	237.23	32.9058
20	239.25	33.0476
25	213.93	31.2356
30	219.57	31.6493
35	185.73	29.0885
40	180.57	28.6776
45	169.93	27.813
50	160.49	27.024
55	133.39	24.611
60	107.88	22.1023
65	91.47	20.3272
70	75.18	18.3975
75	80.43	19.0427
80	49.17	14.8047
85	31.66	11.7895
90	25.03	10.4263
95	16.35	8.31873
100	12.84	7.30006
105	7.09	5.23156
110	5.47	4.50271
115	3.72	3.5558

Table7 channel3 vs fiber length

Fiber Length(Km)	**-Ve Log BER**	**Max.Q-Factor**
5	145.96	25.7458
10	193.37	29.6802
15	185.57	29.0693
20	177.64	28.4369
25	142.44	25.4329

30	155.04	26.5483
35	129.34	24.2222
40	111.22	23.4395
45	115.64	22.888
50	97.85	21.027
55	86.90	19.7981
60	70.85	17.8429
65	60.68	16.4845
70	56.99	15.9641
75	44.22	14.0115
80	34.74	12.369
85	25.86	10.6062
90	20.77	9.44832
95	12.73	7.26553
100	10.12	6.40351
105	7.07	5.23323
110	5.15	4.34519
115	3.10	3.15896

TABLE 8 CHANNEL4 VS FIBER LENGTH

Fiber Length(Km)	**-Ve Log BER**	**Max.Q-Factor**
5	134.87	24.7347
10	81.04	19.0883
15	71.07	17.8494
20	58.67	16.1768
25	53.94	15.4941
30	49.15	14.7706
35	46.37	14.335
40	47.64	14.5401
45	47.94	14.5892
50	47.20	14.4723
55	46.94	14.4336
60	45.37	14.1796
65	40.85	13.4369
70	34.72	12.3538
75	28.98	11.2466
80	22.22	9.78307
85	16.53	8.35956
90	12.09	7.06072
95	9.84	6.3036
100	8.50	5.8108
105	6.90	5.15918
110	5.12	4.3303
115	3.70	3.54077

TABLE9 CHANNEL5 VS FIBER LENGTH

Fiber Length(Km)	-Ve Log BER	Max.Q-Factor
5	171.90	27.9676
10	216.68	31.4357
15	135.15	24.7628
20	121.44	23.4595
25	98.15	21.0522
30	96.08	20.8249
35	95.29	20.7393
40	93.81	20.577
45	88.16	19.9376
50	80.84	19.079
55	68.43	17.5255
60	60.55	16.464
65	55.84	15.7969
70	49.67	14.8772
75	42.68	13.7622
80	35.24	12.4647
85	27.95	11.04595
90	21.28	9.57059
95	15.68	8.13321
100	11.01	6.70821
105	7.46	5.39223
110	5.47	4.50271
115	3.13	3.17648

TABLE10 CHANNEL 6 VS FIBER LENGTH

Fiber Length(Km)	-Ve Log BER	Max.Q-Factor
5	293.24	36.6116
10	139.001	25.1162
15	167.96	27.6429
20	136.72	24.9079
25	142.76	25.4604
30	136.62	24.908
35	126.24	23.926
40	120.28	23.3484
45	109.06	22.2185
50	99.52	21.2116
55	90.62	20.2243
60	82.92	19.3303
65	69.73	17.6971
70	54.88	15.6581
75	47.69	14.5704
80	44.62	14.0814
85	32.51	11.9528
90	19.71	9.19042
95	15.70	8.19952
100	12.43	7.17168
105	8.21	5.69525
110	5.15	4.34519
115	3.58	3.46791

TABLE11 CHANNEL7 VS FIBER LENGTH

Fiber Length(Km)	-Ve Log BER	Max.Q-Factor
5	247.35	33.6034
10	249.71	33.7653
15	226.14	32.1197
20	205.54	30.6094
25	156.67	26.6875
30	149.32	26.0471
35	133.62	24.6242
40	110.02	22.3148
45	113.28	22.648
50	105.22	21.8182
55	105.007	18.7382
60	75.30	18.407
65	61.23	16.562
70	56.20	15.8519
75	44.96	14.1356
80	37.84	12.9328
85	28.72	11.2047
90	17.7	8.6165
95	13.46	7.48657
100	8.48	5.798
105	6.47	5.96846
110	5.54	4.02553
115	3.27	3.2709

TABLE 12 CHANNEL8 VS FIBER LENGTH

Fiber Length(Km)	-Ve Log BER	Max.Q-Factor
5	296.52	39.4599
10	286.52	36.1885
15	250.12	33.7964
20	220.86	31.7418
25	190.68	29.4744
30	170.42	27.8479
35	135.62	25.7199
40	139.74	25.1896
45	141.45	25.3484
50	107.43	22.0519
55	112.39	22.5632
60	82.36	19.2689
65	85.95	19.6921
70	66.68	17.3038
75	55.06	15.6872
80	41.64	13.887
85	26.57	10.7593
90	23.25	10.0294
95	12.66	7.2456
100	11.78	6.96457
105	7.45	5.39058
110	4.99	4.26135
115	3.75	3.5713

Table 13 Performance Para at Frequency Spacing of 100GHz

CHANNEL	I/P OSNR(dB)	O/P OSNR(dB)	DISPERSION(ps/nm)
01	74.928597	8.37595×10^{1}	1.64209×10^{8}
02	72.445256	8.3779×10^{1}	1.36190×10^{8}
03	72.409317	8.37623×10^{1}	1.18240×10^{8}
04	72.514949	8.38244×10^{1}	1.39053×10^{8}
05	72.461568	8.38436×10^{1}	1.80291×10^{8}
06	72.488921	8.38083×10^{1}	2.20723×10^{8}
07	72.408704	8.37159×10^{1}	4.44501×10^{7}
08	75.400067	8.37601×10^{1}	1.69383×10^{8}

Table14 Performance Para at Frequency Spacing of 110GHz

CHANNEL	I/P OSNR(dB)	O/P OSNR(dB)	DISPERSION(ps/nm)
01	78.693192	8.37487×10^{1}	1.63580×10^{8}
02	63.148292	6.51979×10^{1}	1.33043×10^{8}
03	44.210924	4.34870×10^{1}	1.18495×10^{8}
04	25.830412	2.97706×10^{1}	1.41919×10^{8}
05	19.10056	1.99079×10^{1}	1.79665×10^{8}
06	22.114225	1.22281×10^{1}	2.18461×10^{8}
07	14.23428	5.84062	4.25358×10^{7}
08	14.800685	5.0121×10^{-1}	1.69162×10^{8}

Table15 Performance Para at Frequency Spacing of 130GHz

CHANNEL	I/P OSNR(dB)	O/P OSNR(dB)	DISPERSION(ps/nm)
01	80.80653	8.37487×10^{1}	1.63515×10^{8}
02	28.880226	2.97954×10^{1}	1.32861×10^{8}
03	13.671252	5.83081×10^{1}	1.17506×10^{8}
04	30.428228	0.00000	1.41359×10^{8}
05	37.585111	0.00000	1.80231×10^{8}
06	40.546794	0.00000	2.18682×10^{8}
07	38.802522	0.00000	4.26938×10^{7}
08	36.125302	0.00000	1.69404×10^{8}

Table16 Performance Para at Frequency Spacing of 150GHz

CHANNEL	I/P OSNR(dB)	O/P OSNR(dB)	DISPERSION(ps/nm)
01	88.007286	8.37487×10^{1}	1.63513×10^{8}
02	26.022678	1.22150×10^{1}	1.93736×10^{8}
03	33.878601	0.00000	1.17363×10^{8}
04	42.036184	0.00000	1.41520×10^{8}
05	37.043135	0.00000	1.80235×10^{8}
06	33.166824	0.00000	2.19158×10^{8}
07	29.931141	0.00000	4.28969×10^{7}
08	27.253876	0.00000	1.69467×10^{8}

X. Eye Diagrams

Eye diagrams are generated at the reception end of WDM System and are a means of measuring the quality of signal trans-reception. Better eye opening means better signal trans-reception. Comparison of eye opening were made on altering the various system parameters and noting the corresponding change in the eye opening and performance evaluating parameters. All the performance evaluating parameters can be extracted from the corresponding eye diagrams. Various Eye diagrams were generated against various varying system parameters some of them are shown below.

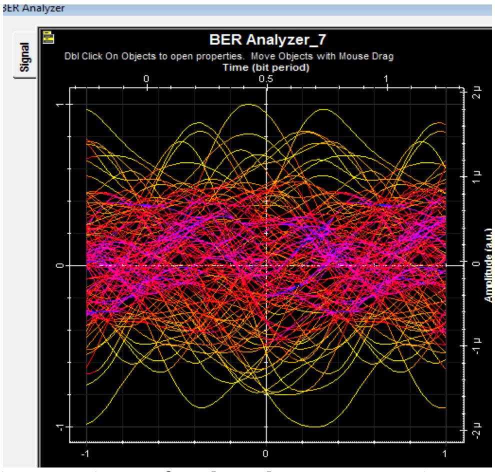

Fig 4 Eye Diagram for Channel8 at 10GHz spacing

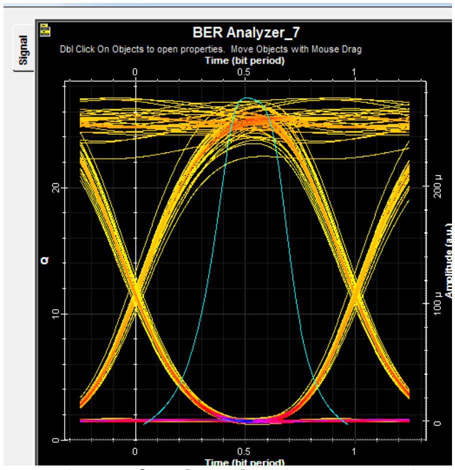

Fig 5 Eye Diagram for Channel8 at 100 GHz spacing

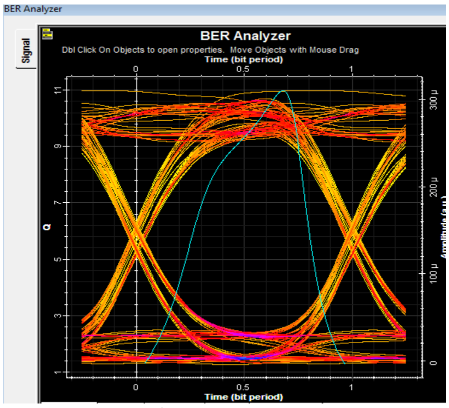

Fig.6 Eye Diagram for Channel 1 at 193.1THz

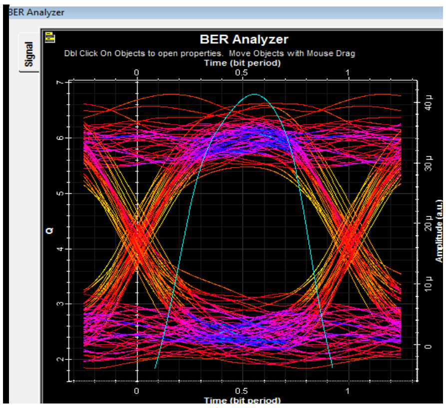

Fig. 7 Eye Diagram for Channel 1 at 199THz

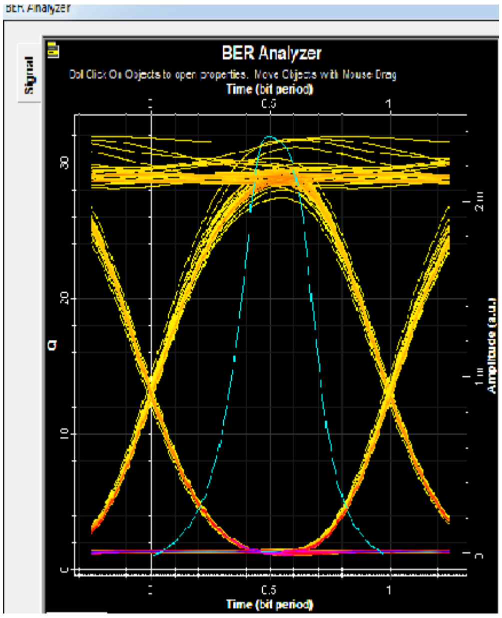

Fig.8 Eye Diagrams for Channel 1 at 5Km Fiber Length

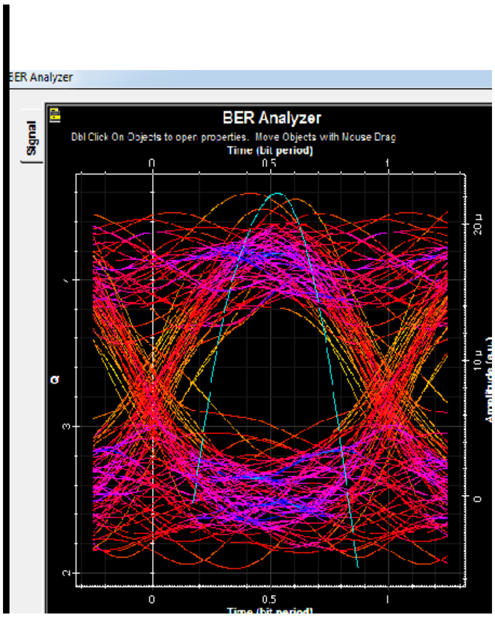

Fig.9 Eye Diagram for Channel 1 at 110 Km

XI. **Simulation Graphs**

The data retrieved from various eye diagrams at the receiving BER analyser was extracted and plotted.Thus the dependencies of various performance evaluating parameters onto various system parameters has been plotted graphically which are shown as follows

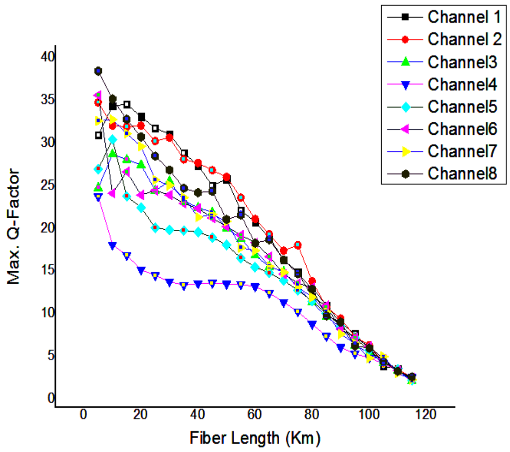

Fig.10 Max Q-Factor Vs Fiber Length(With EDFA)

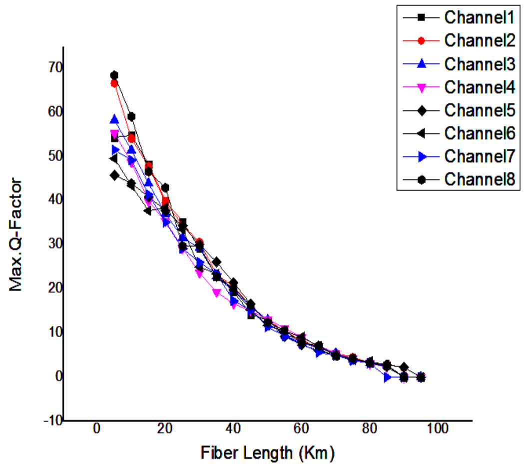

Fig.10 Max Q-Factor Vs Fiber Length(Without EDFA)

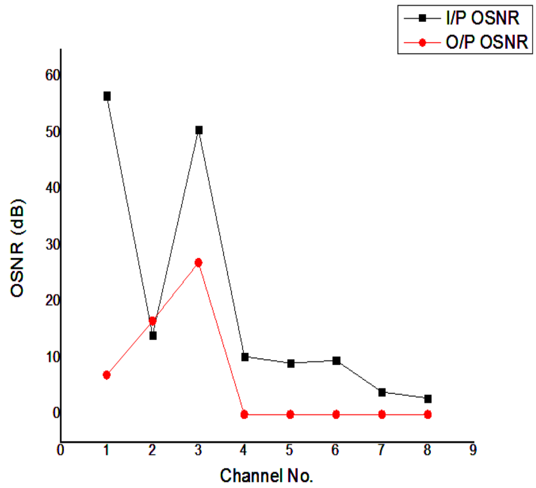

Fig.11 OSNR of Various Channels at 30GHz frequency Spacing

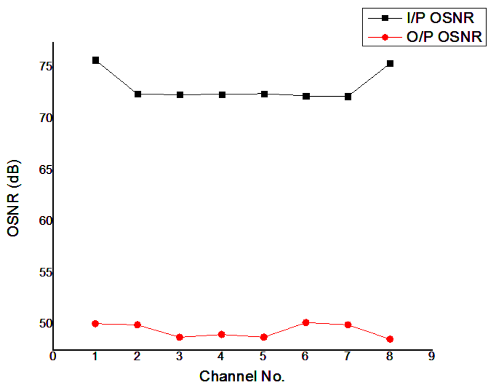

Fig.12 OSNR of Various Channels at 100GHz frequency Spacing

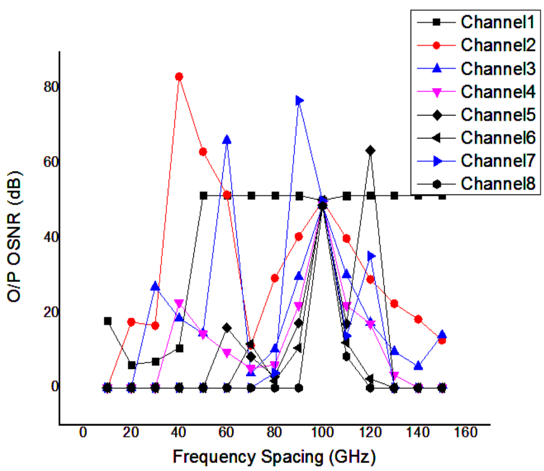

Fig.13 O/P OSNR Vs Frequency Spacing

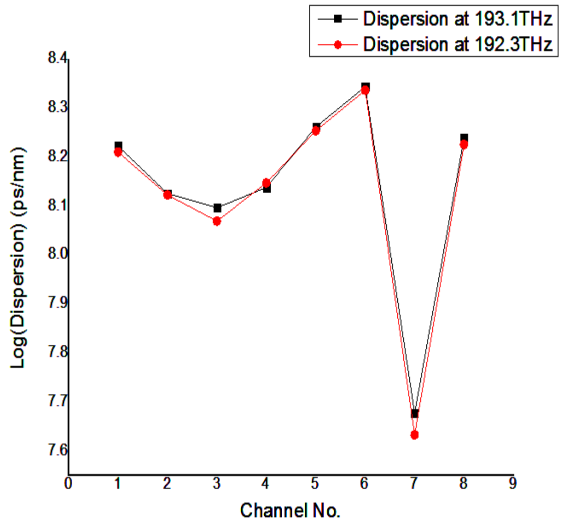

Fig.14 Dispersion across Various Channels

XII. **Discussions From Graphs**

From the above graphs it was observed that

A. BER Increases with Fiber length,and maximum fiber length which the system could support was found out to be 110 Kms with EDFA and 90 Kms without EDFA

B.OSNR of all channels dropped as the frequency spacing was reduced and best OSNR was seen around frequency spacing of 100GHz.

C. Difference between I/P OSNR and O/P OSNR was seen minimum when operated at frequency spacing of around 100GHz

D. Dispersion first increased reached a maximum and then decreased to reach a minimum (Channel7) at channel frequency set at 193.8 THz.

XIII.**Conclusion**

Here the dependencies of various performance evaluating parameters i.e. Min.BER, Max. Q-Factor, Eye Opening, Dispersion and OSNR on various system parameters i.e. Fiber length, Operating Channel Frequencies, Adjacent channel spacing , and EDFA gain were evaluated .The obtained results were found in well accordance with real results.

REFERENCES

[1] Jun Zheng & Hussein T.Mouftah, Optical WDM networks, concepts and Design, IEEE press, John Wiley – Sons, Inc., Publication, p.1-4, 2004.

[2] R. Ramaswami, K.N. Sivarajan, "Optical Networks-A Practical Perspective, Second Edition, Morgan Kaufmann -Publishers An Imprint Of Elsevier , New Delhi, India, 2004

[3] G. Ramesh, S. Sundaravadivelu, "Reliable Routing and Wavelength Assignment Algorithm for Optical WDM Networks", European Journal of Scientific Research ISSN 1450-216X Vol.48 No.1, 2010.

[4] A.S. Acampora," A multichannel multihop local light wave net-work", Proceedings, IEEE Globecom'87, Tokyo, Japan, Vol.3, 1987