Experiment - 1

Aim:- To create a network in which a 10 Gb/s NRZ optical signal is launched into 50km of standard single mode fiber with PIN photo detector as the reciever.

Measurements :- Measurements include the electrical spectrum, eye diagram and Q estimation

Components :-

- Transmitter section

  Logical sources : Data Source

  Laser sources : CW Lorentzian Laser

  Optical Modulator : sin2 amplitude modulator

  Modulator Driver : NRZ Rectangular

- Channel

  fiber

- Reciever section

  Sensitivity reciever section

- Measurements Components

  Optical power meter, optical spectrum analyser, electrical scope.

Procedure:-

1. Create the network as shown in diagram. Check the properties of each component.
2. Simulate the network.
3. ~~Create~~ Compare the readings of two power meters and find out the reason for difference.
4. Check the optical spectrum analyser's waveform and compare the center frequency with the frequency of laser source.
5. Check the waveform of electrical scope and find out the readings for Eye opening, closing, Q factor, jitter, BER, etc.

Result :-

- Optical power at opowme1

  Power (dBm) = -6.053

  Power (mW) = 0.248E+00

- Optical power at opowme 2

  Power (dBm) = -16.032

  Power (mW) = 0.249E-01

- Bit error rate (BER)

  1.96e-29

- Q-factor

  21.19dB

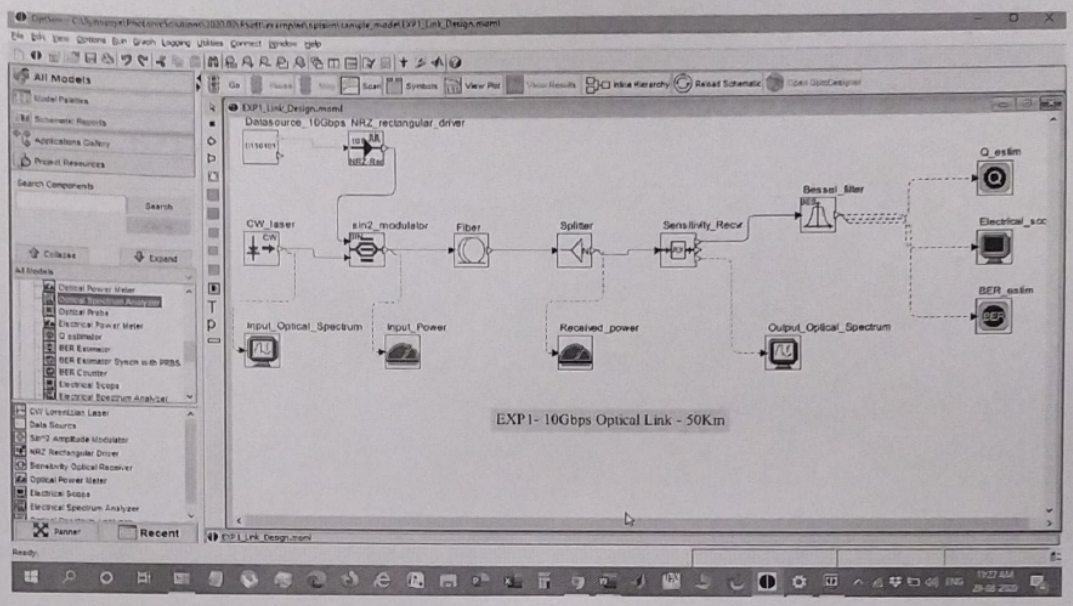
Conclusion :-

Eye Diagram is observed and estimations are done. The readings of optical power meters are different, due to the length of fiber and losses like sensitivity loss, etc.

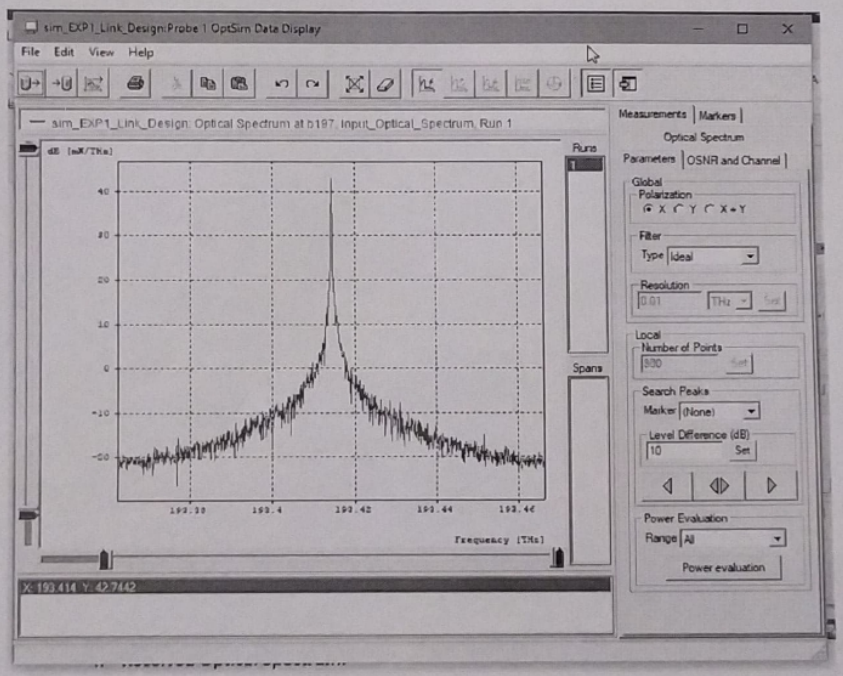
EXPERIMENT 1

Aim:

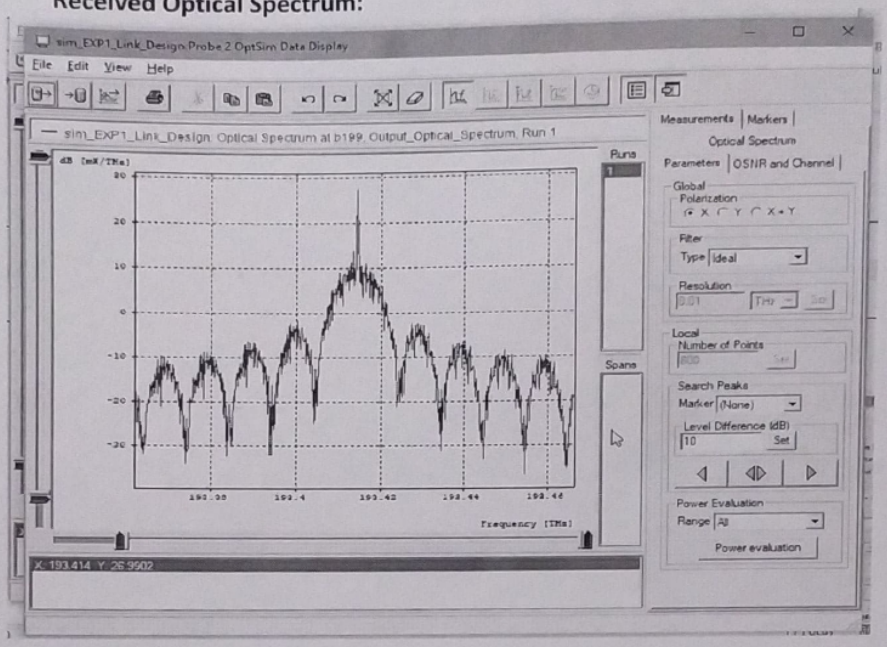
To create a network in which a 10 Gb/s NRZ optical signal is launched into 50 km of standard single mode fibre with PIN photo detector as the receiver.



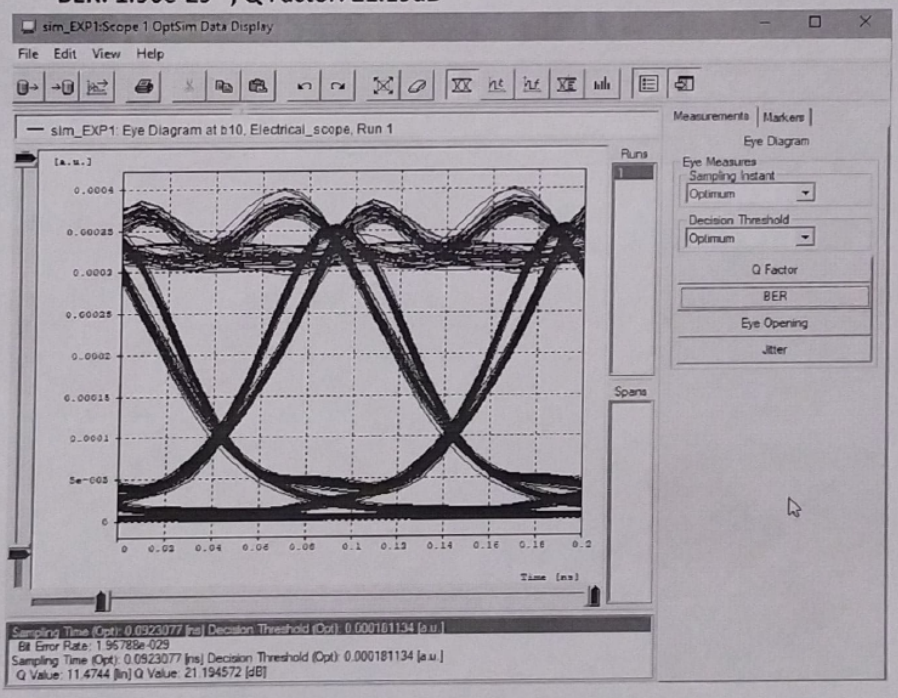
Input Optical Spectrum:



Received Optical Spectrum:



BER: 1.96e-29 , Q Factor: 21.19dB



For the labs of BVCOE, New Delhi

Experiment - 2

Aim :- To study the performance of an optical link by varying length of transmission fiber using the parameter scan feature.

Measurements :-

Measurements include electrical spectrum, eye diagram, Q estimation

Components :-

- Transmitter section - Data source, Laser source, amplitude modulator, modulator driver.
- Channel - Single Mode fiber
- Reciever section - Sensitivity Optical Reciever
- Measurement components - Optical power meter, optical spectrum analyser, electrical spectrum.

Procedure :-

1. Create the network as shown. Check the properties of each component.
2. Click on symbol button. Then click on add button. Type a parameter L and value as 10.0.
3. Click on fiber properties/length. Assign value 'L' as the length of fiber.
4. Click on scan button, then click on add column. Param1 as L will be appeared.
5. Click on append row for 6 times. Assign the values of L as 10, 20, 30, 40, 80, 100.
6. Compare the results for all the values. You will find the poorer response as the length increases.
7. Check the optimal spectrum analyser's waveform for all values of L.
8. Check the waveform of electrical scope and find out the readings for eye opening, closing, Q factor, jitter, BER, etc for all values of L.

Observations :-

Run	Optical power at opowme1		Optical power at opowem 2	
	dBm	mW	dBm	mW
1	-6.032	0.249E+00	-8.079	0.156E+00
2	-6.032	0.249E+00	-10.111	0.975E-01
3	-6.032	0.249E+00	-12.107	0.616E-01
4	-6.032	0.249E+00	-14.093	0.390E-01
5	-6.032	0.249E+00	-22.051	0.624E-02
6	-6.032	0.249E+00	-25.864	0.253E-02

Result:-

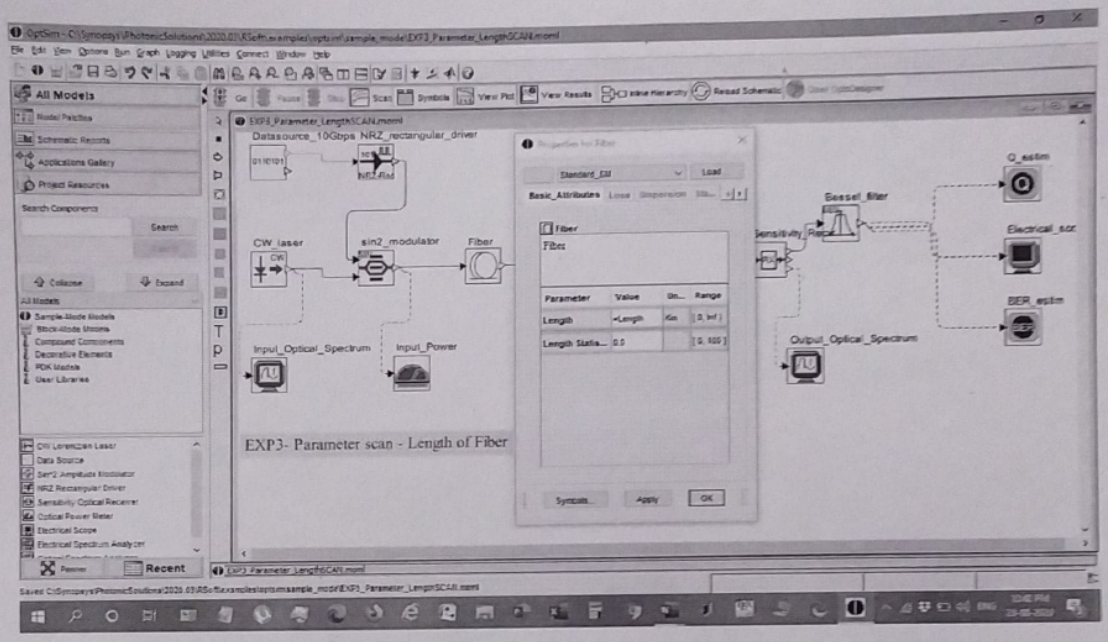
The reading of optical meter 1 remains same for different values of lengths of fiber because it is situated before the fiber. The readings of optical power meter 2 keeps varying with the length, it decreases with increase in length.

The Q-factor also decreases with increase in length. The BER increases with increase in length, so the performance is poor due to attenuation, losses, etc. Jitter value increases with increase in length of fiber.

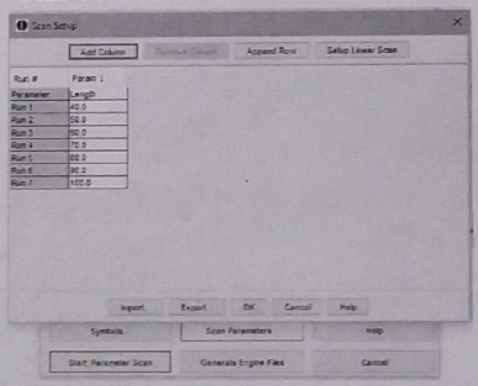
EXPERIMENT 2

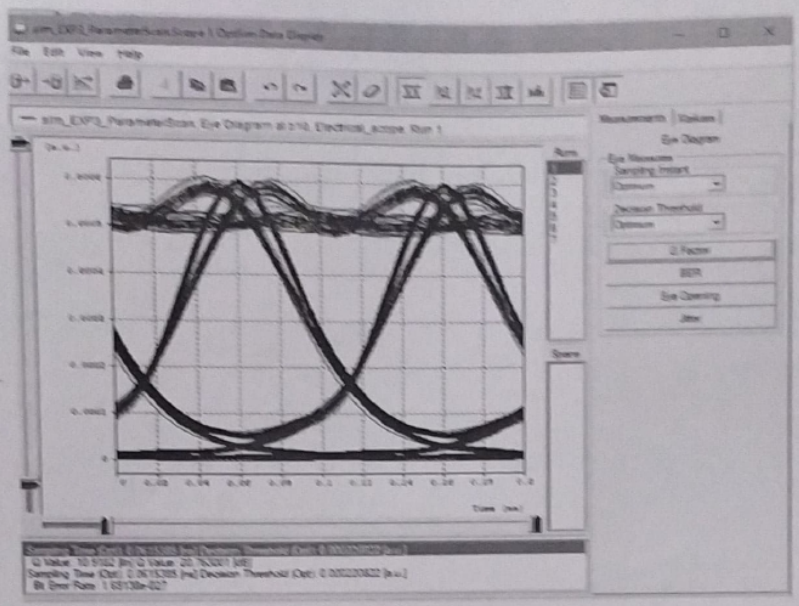
Aim:

To study the performance of an optical link by varying length of transmission fibre using the PARAMETER SCAN feature.

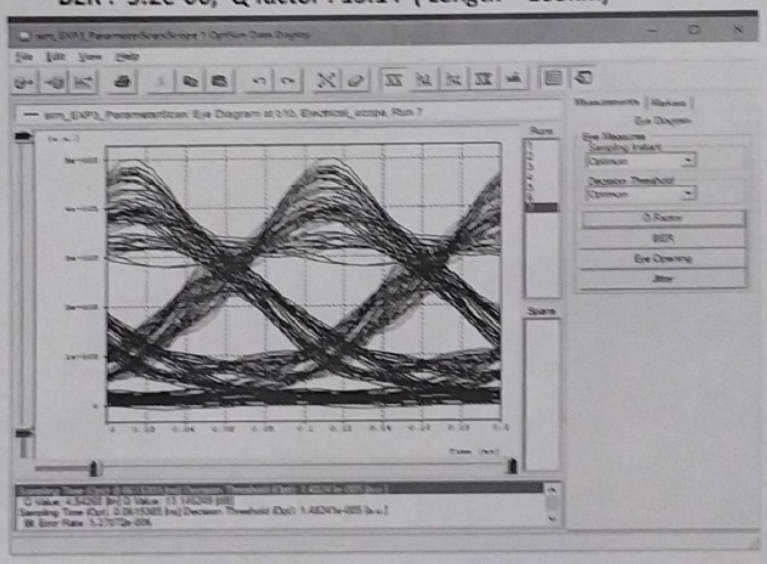


Scan Parameters

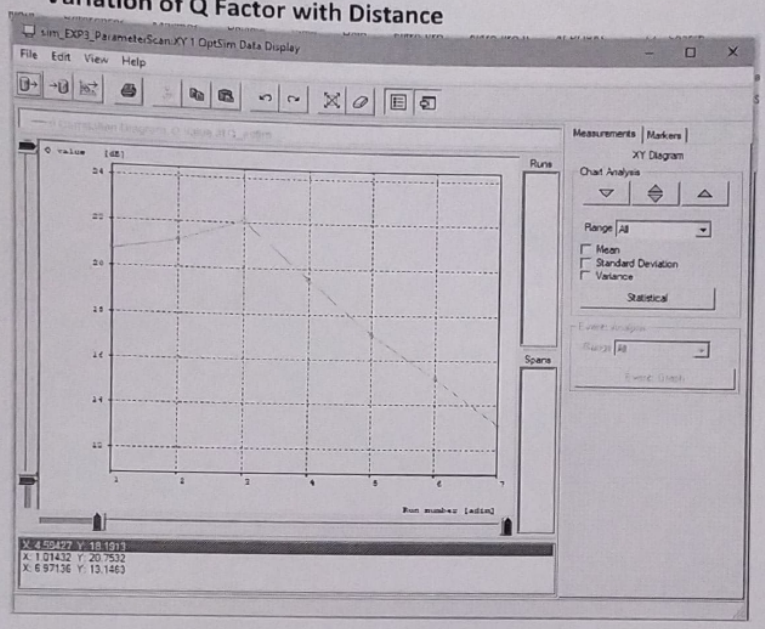




BER : 5.2e-06, Q factor : 13.14 (Length – 100km)



Variation of Q Factor with Distance



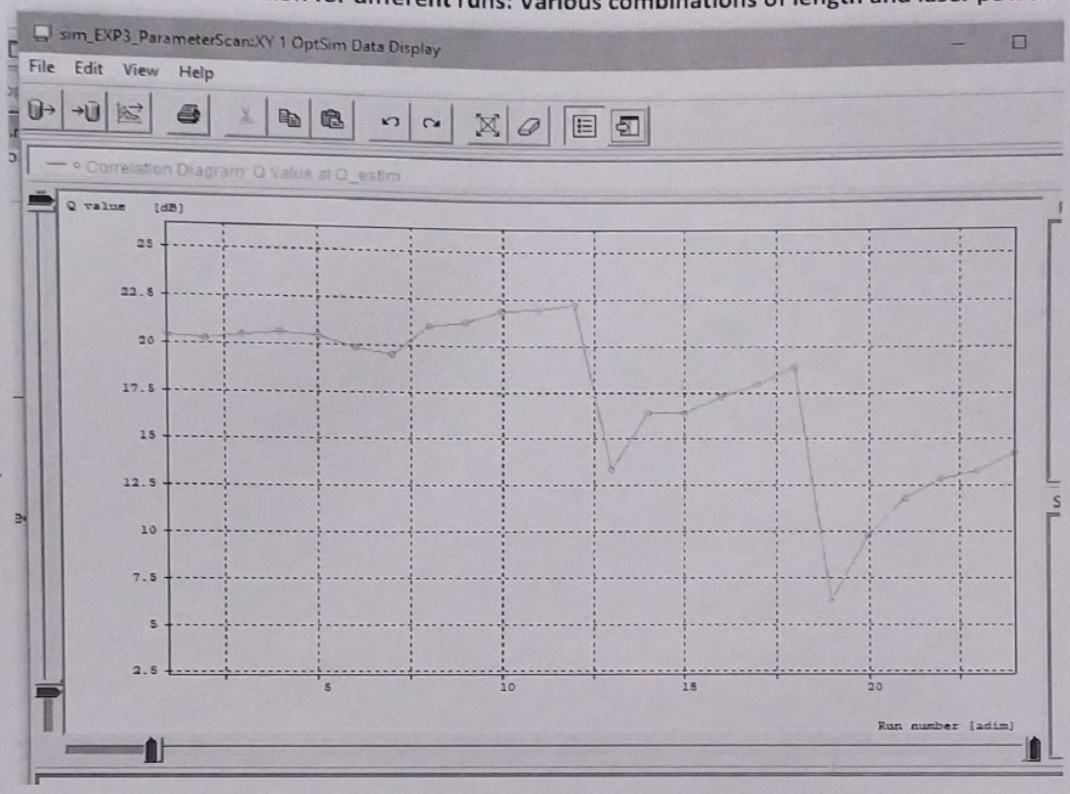
1. **Parameter Scan with both <u>length of fibre</u> and <u>power of laser</u>.**
   Length: 40, 60, 80, 100 km (Increment: 20Km)
   Laser Power : -5, -2, 1, 4, 7, 10dBm (Increment : 3dBm)

Scan Setup

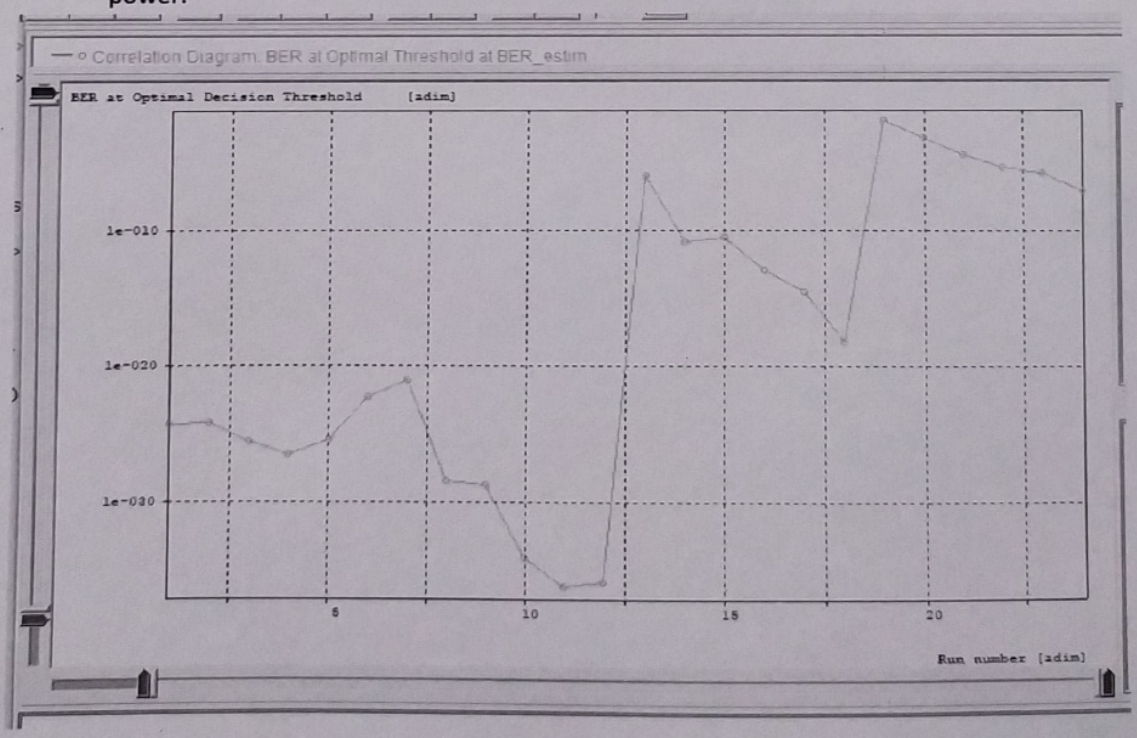
Add Column Remove Co

Run #	Param 1	Param 2
Parameter	length	power
Run 1	40.0	-5.0
Run 2	40.0	-2.0
Run 3	40.0	1.0
Run 4	40.0	4.0
Run 5	40.0	7.0
Run 6	40.0	10.0
Run 7	60.0	-5.0
Run 8	60.0	-2.0
Run 9	60.0	1.0
Run 10	60.0	4.0
Run 11	60.0	7.0
Run 12	60.0	10.0
Run 13	80.0	-5.0
Run 14	80.0	-2.0
Run 15	80.0	1.0
Run 16	80.0	4.0
Run 17	80.0	7.0
Run 18	80.0	10.0
Run 19	100.0	-5.0
Run 20	100.0	-2.0
Run 21	100.0	1.0
Run 22	100.0	4.0
Run 23	100.0	7.0
Run 24	100.0	10.0

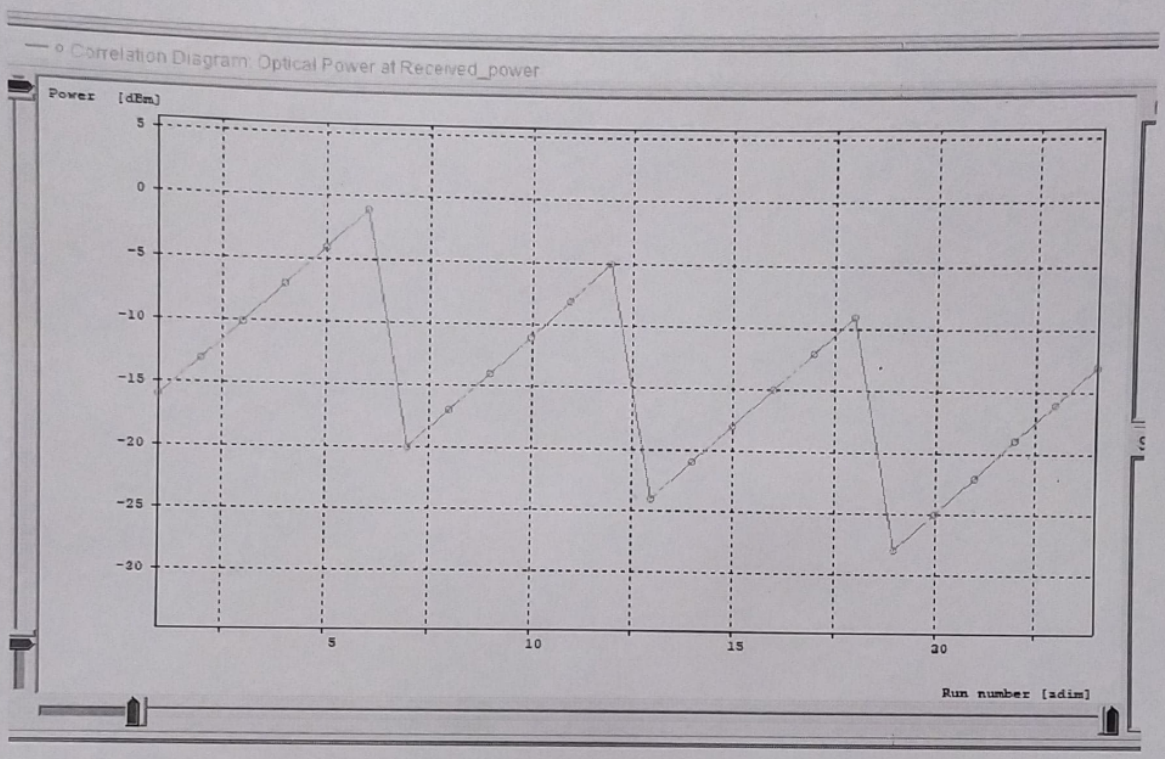
Q Factor variation for different runs: Various combinations of length and laser power.



BER Factor variation for different runs: Various combinations of length and laser power.



2. **Received Optical Power for various RUNS**



Experiment - 3

Aim :- To create 10 GB/s optical link of standard single mode fiber using 980 nm pumped EDFA as a preamplifier. Study of performance of the link with EDFA as post and inline amplifier.

Measurements :-

Measurements include the electrical spectrum, eye diagram and Q estimation

Components :-

- Transmitter section - Data source, Laser source, amplitude modulator, Modulator driver
- Channel - Single mode fiber
- Reciever section - sensitivity optical reciever, filters, EDFA
- Measurement components - optical power mete, optical spectrum analyser, electrical scope.

Procedure :-

1. Create the network by selecting the components from the Model Palettes as shown. Check the properties of each component.
2. Simulate the network.
3. Check the waveform of electrical scope and find out the readings for eye opening, closing, Q factor, jitter, BER, etc.
4. Compare the readings of two electrical scopes and find out the reason for difference. Compare them using superimpose option. For this, open one waveform then go to Optsim data display block. Then click on another waveform. Then click on superimpose button.

Observations :-

	BER	Q-factor
Preamplifier	8.74e-30	21.16 dB
Post amplifier	6.38e-24	20.19 dB
Inline amplifier	4.7e-20	19.38 dB

Result :-

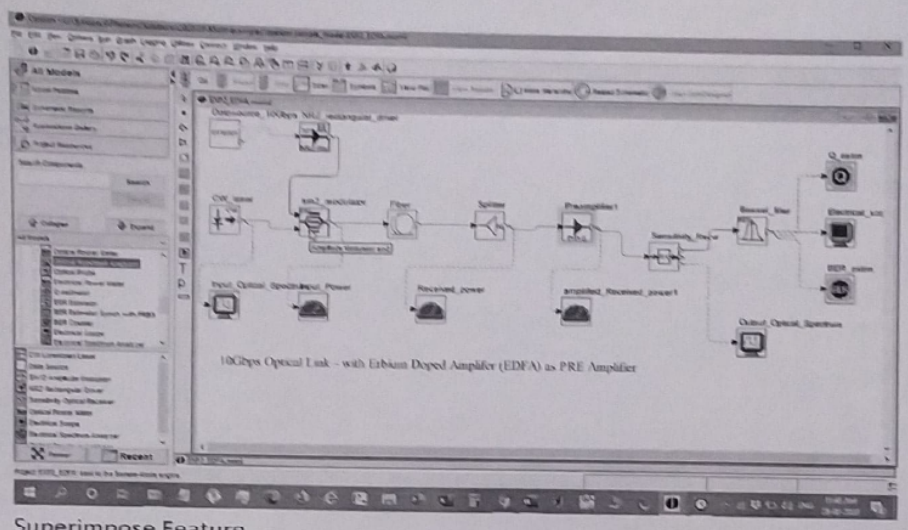
The Q factor in case of EDFA increases as that of without EDFA, so it shows EDFA is used for compensating the losses. Also, the closure of eye decreases, that means the strength of signal increases. The electrical spectrum using EDFA before and after filter varies from -90dB to -140 dB. But in case of without using EDFA, the electrical spectrum before filter is at -140 dB and after filter, it varies from -20 dB to -70 dB.

Also, EDFA helps in compensating the losses that occur after going through the filter. So, it should be used for having a good strength of signals.

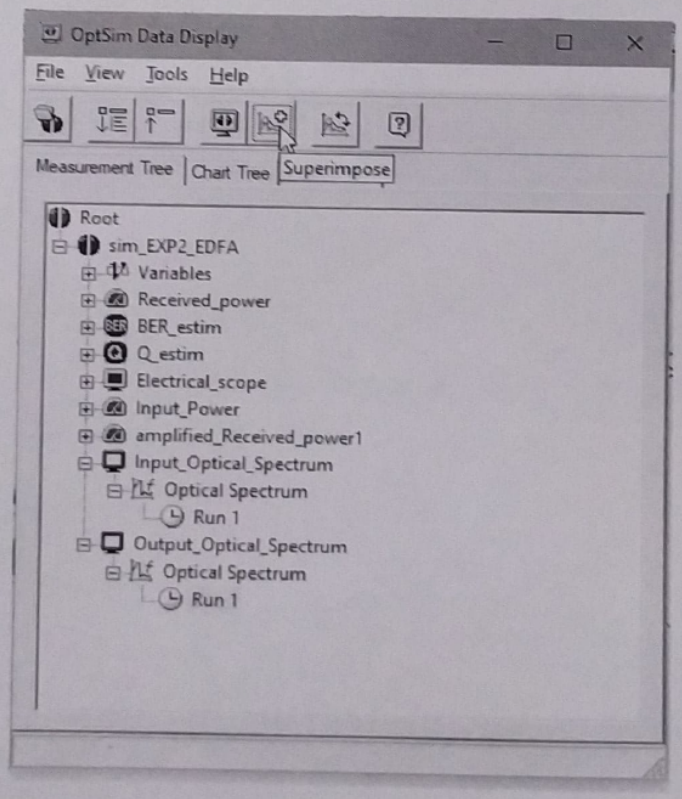
EXPERIMENT 3

Aim:

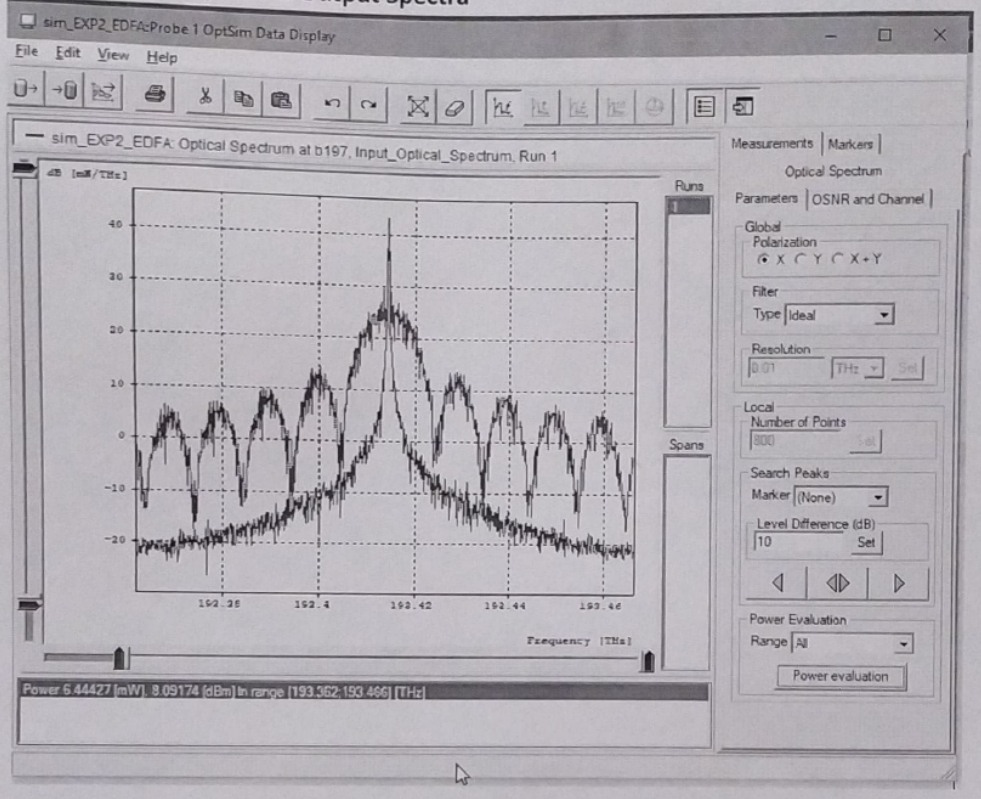
To create 10 Gb/s optical link of standard single mode fiber using 980-nm pumped EDFA as a PRE-Amplifier. Study of performance of the link with EDFA as POST and INLINE Amplifier.



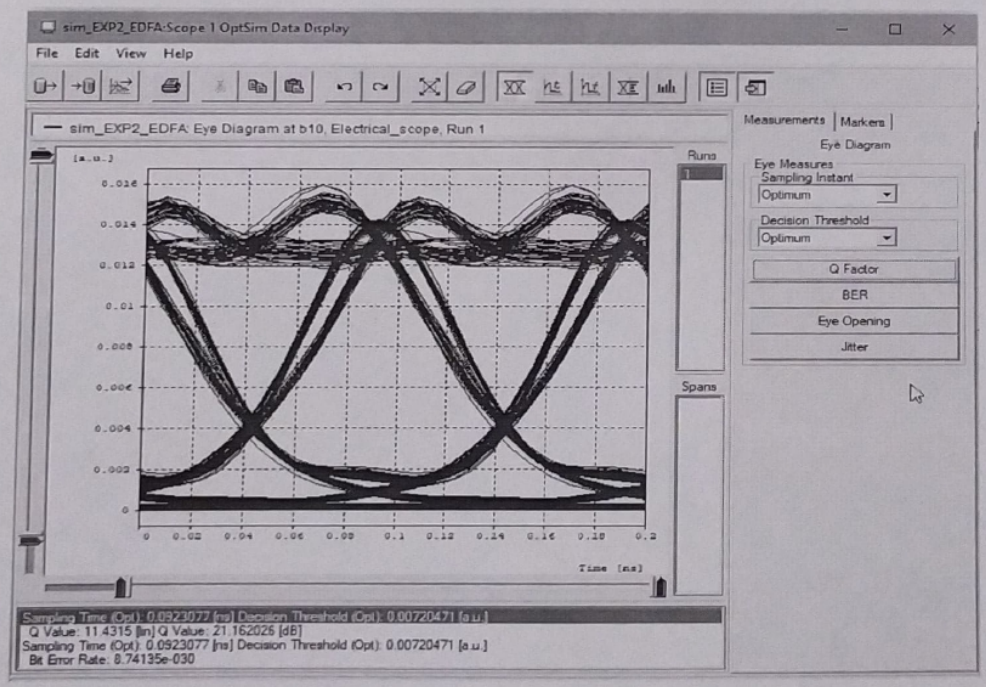
Superimpose Feature



Superimposed Input and Output Spectra

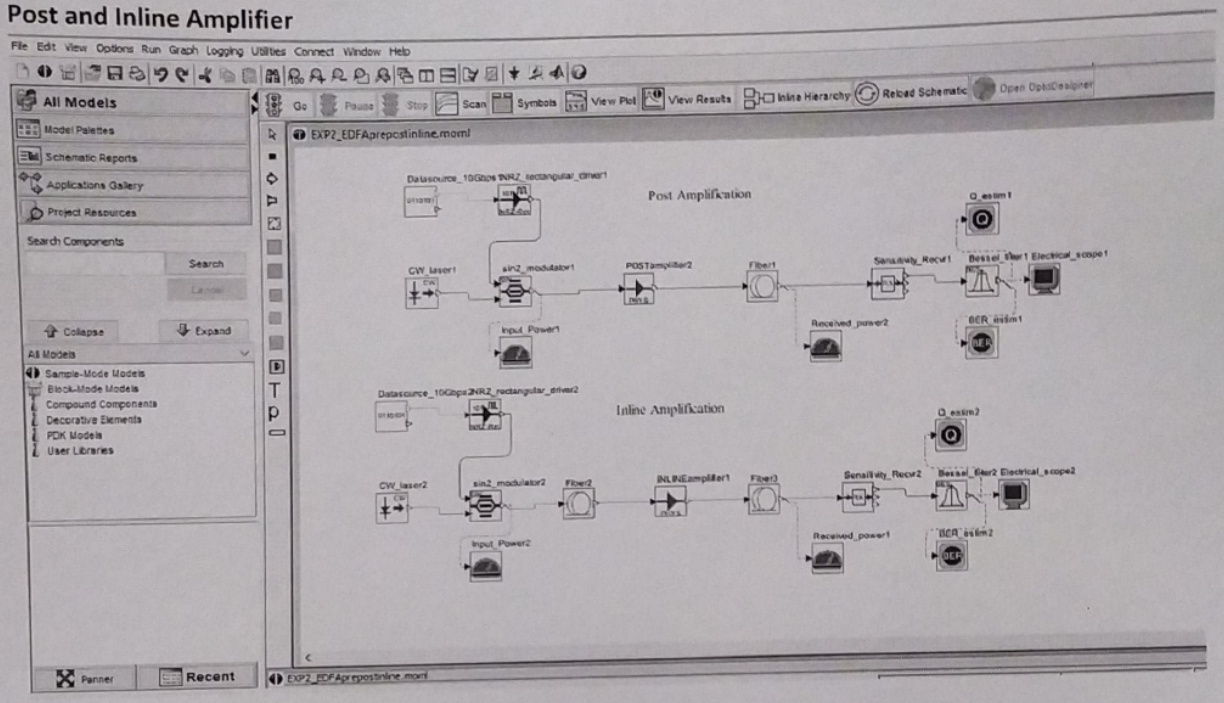


BER : 8.74e-30, Q factor :21.16dB



For the labs of BVCOE, New Delhi

Post and Inline Amplifier



1. **BER : 6.38e-24, Q factor : 20.19 dB (POST Ampifier)**
2. **BER : 4.7 e-20, Q factor : 19.38 dB (INLINE Amplifier)**

Experiment-4

Aim :- Study of 10 Gb/ps NRZ optical signal launched into 5 spans of comprising of Dispersion Shifted Fiber (DSF), each 50km in length followed by inline EDFA for loss compensation.

Measurements :-

Measurements include the optical spectrum, detected electical spectrum, eye diagram and Q estimation.

Procedure :-

1. Open the optsim and create the network by selecting the components from the model palettes as shown. Check the properties of each component.
2. Simulate the network.
3. Check the waveform of all optical spectrums by superimposing them. Also look eye diagram in electrical scope and ~~fid~~ find out the readings for eye opening, closing, Q factor, jitter, BER, etc.
4. Compare the readings of electrical spectrum in two electrical scopes and find out the reason for difference. Compare them using superimpose option. For this, open one waveform then go to Optsim data display block. Then click on another waveform. Then click on superimpose button.

Observations :-

BER = 4.8e-40 Q-factor = 22.53 dB

Optical power before transmission

Power (dBm) = -2.878

Power (mW) = 0.515E+00

Optical power after 5 spans of DSF transmission

Power (dBm) = 6.152

Power (mW) = 0.412E +01

Result :-

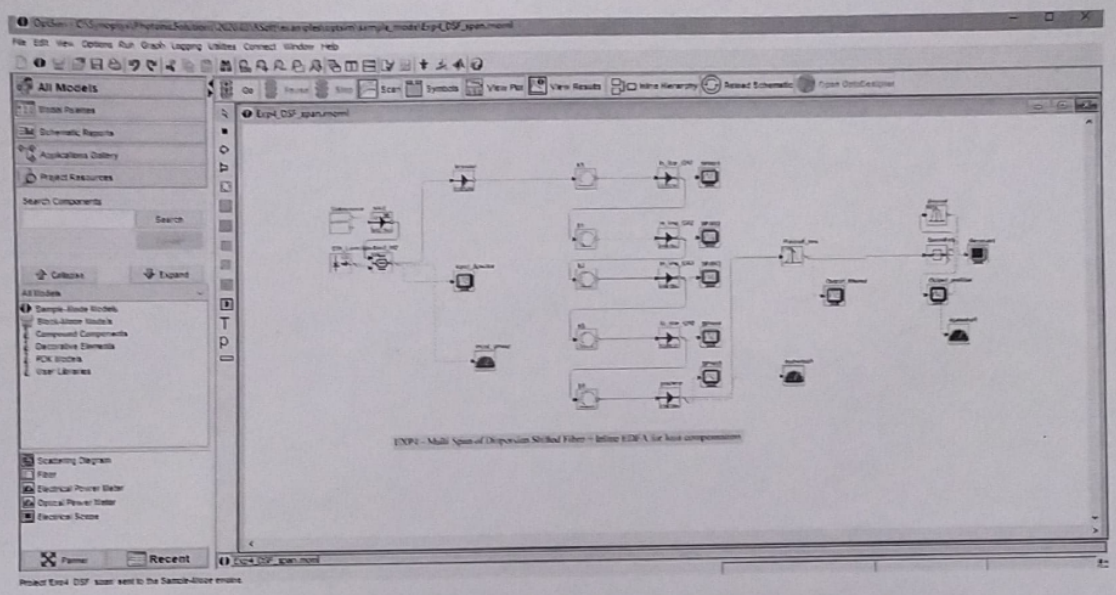
Q factor is decreased while using a single span of fiber, so it means deterioration occurs to more extent than that with five spans of fibers. The purpose of a filter is to narrow down frequency band.

Jitter increases with the increase in length of fiber. The closure of eye increases while using a single span of fiber, it shows deterioration occurs to more extent than that using five spans of fiber. So, it is better to use five spans of fibers of each 50km length rather than single span fiber because as length increases losses also increase. So, to compensate losses use EDFA.

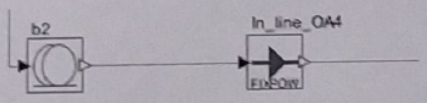
EXPERIMENT 4

Aim:

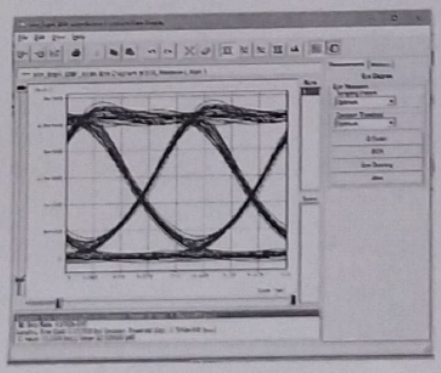
Study of 10 Gb/s NRZ optical signal launched into 5 spans of comprising of Dispersion Shifted Fiber (DSF), each 50 km in length followed by INLINE EDFA for loss compensation.



Single Span of 50km DSF and Inline Optical Amplifer



BER: 4.8 e-40, Q Factor : 22.53dB

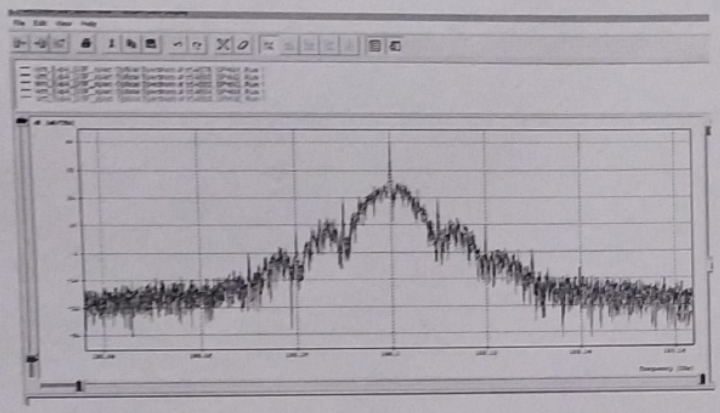


1. **Power**

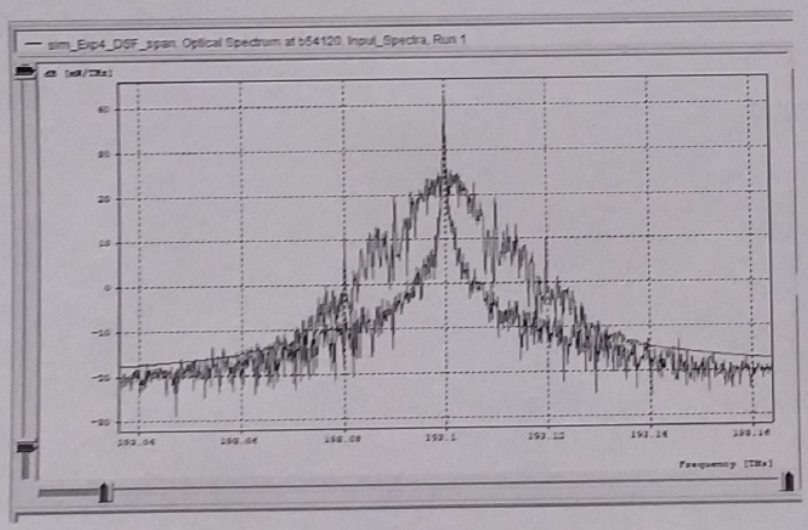
Optical Power before Transmission:

Power [dBm] = -2.878
Power [mW] = 0.515E+00
Optical power after 5 Spans of DSF Transmission
Power [dBm] = 6.152
Power [mW] = 0.412E+01

Superimposed Input Spectra after 5 Spans :

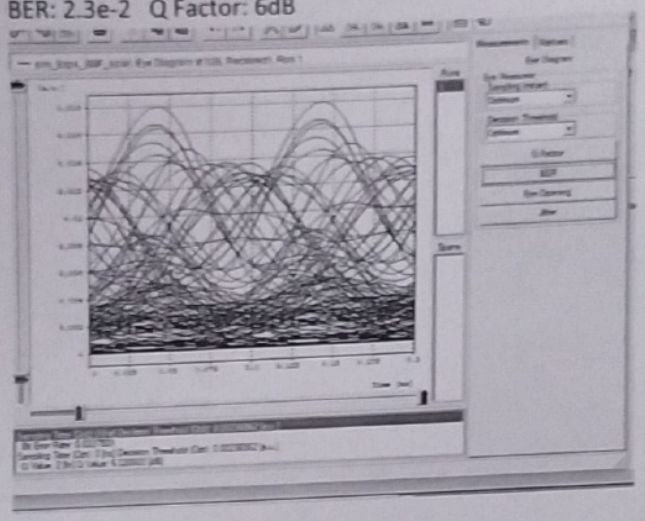


Superimposed Input and Output Spectra



5 SPANS with SMF (Note the perfromance decrease)

BER: 2.3e-2 Q Factor: 6dB



EXPERIMENT 5

For the labs of BVCOE, New Delhi

Experiment -5

Aim:- Study of 10 Gb/s NRZ optical signal launched into 5 spans of comprising of dispersion shifted fiber (DSF) each 50km in length followed by inline EDFA for loss compensation in an iteration loop. The parametric feature used to show to vary the optical attenuation at the reciever.

Measurements:-

Measurements include the optical spectrum, detected electrical spectrum, eye diagram and Q-estimation.

Observations:-

- Run I

  BER = 4.76e-39

  Q factor = 22.29 dB

  Rx attenuation = 23 dB

- Run II

  BER = 2.84e-7

  Q factor = 14.14 dB

  Rx attenuation = 33 dB

Result:-

With increase in attenuation, Q factor decreases. Hence, the strength of signal also decreases.

With increase in attenuation, the closure of the eye in eye diagram increases.

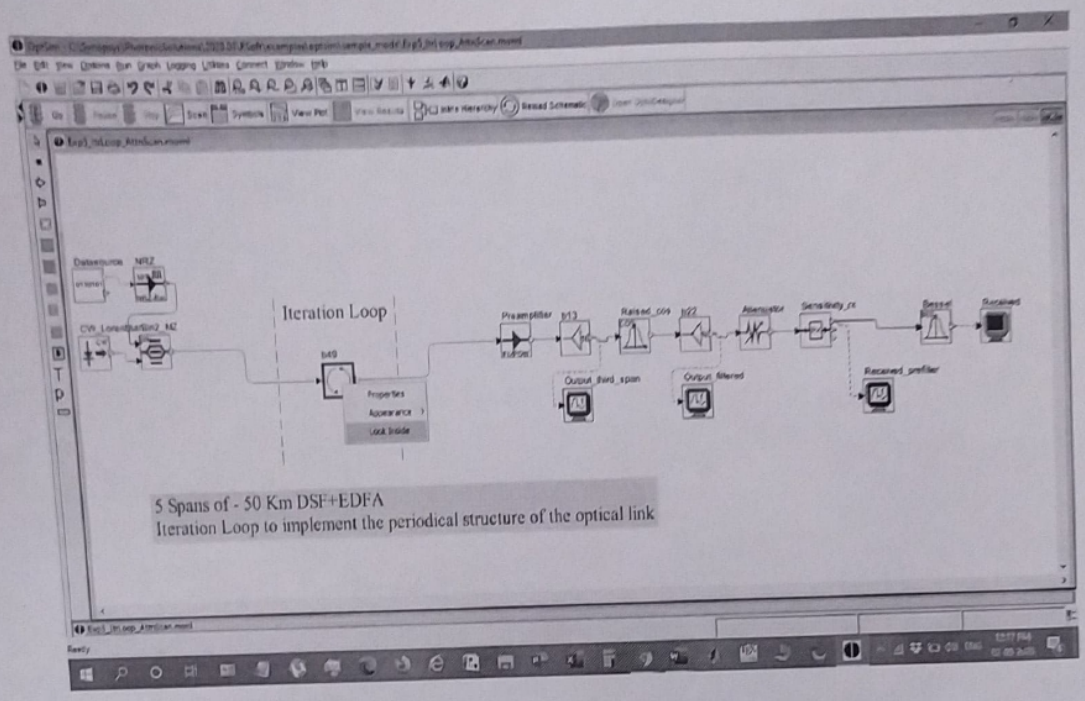
From the optical spectrum, the center emission frequency is same as that of input laser frequency but the power of the signal decreases with increase in attenuation.

The dispersion shifted numerical fiber operate at 1550nm. And at 1550nm, less dispersion and attenuation occurs.

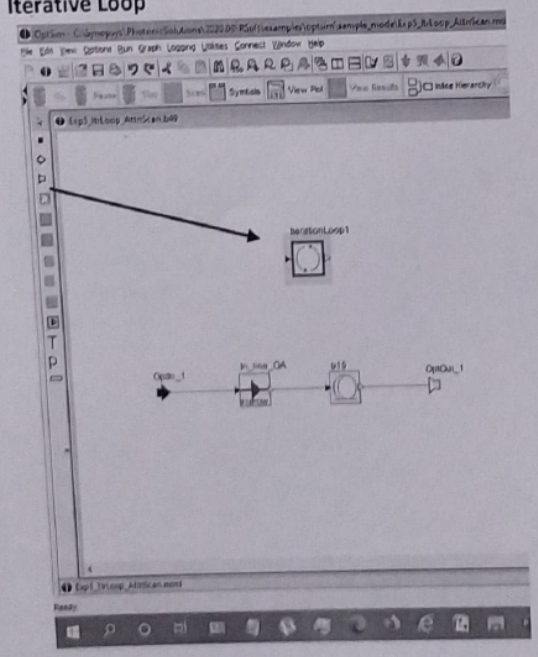
With increase in attenuation, the jitter decreases, so the delay of signal from transmission to reception decreases.

Aim:

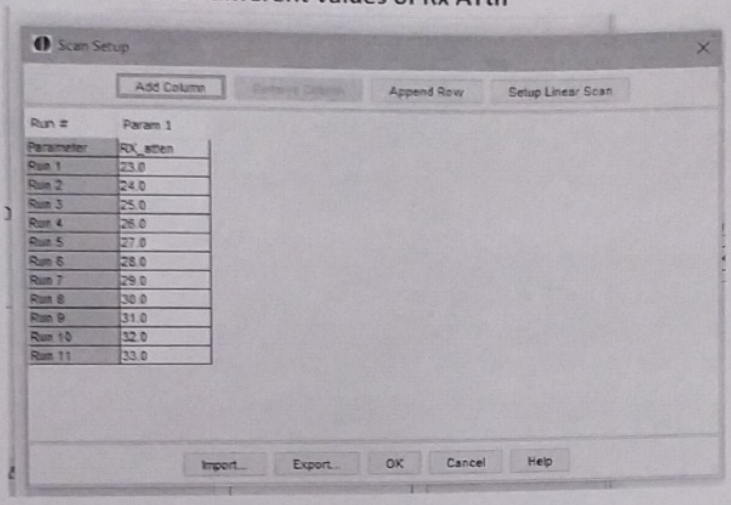
Study of 10 Gb/s NRZ optical signal launched into 5 spans of comprising of Dispersion Shifted Fiber (DSF), each 50 km in length followed by INLINE EDFA for loss compensation in an ITERATION LOOP. The parametric run feature used to show to vary the optical attenuation at the receiver.



Iterative Loop

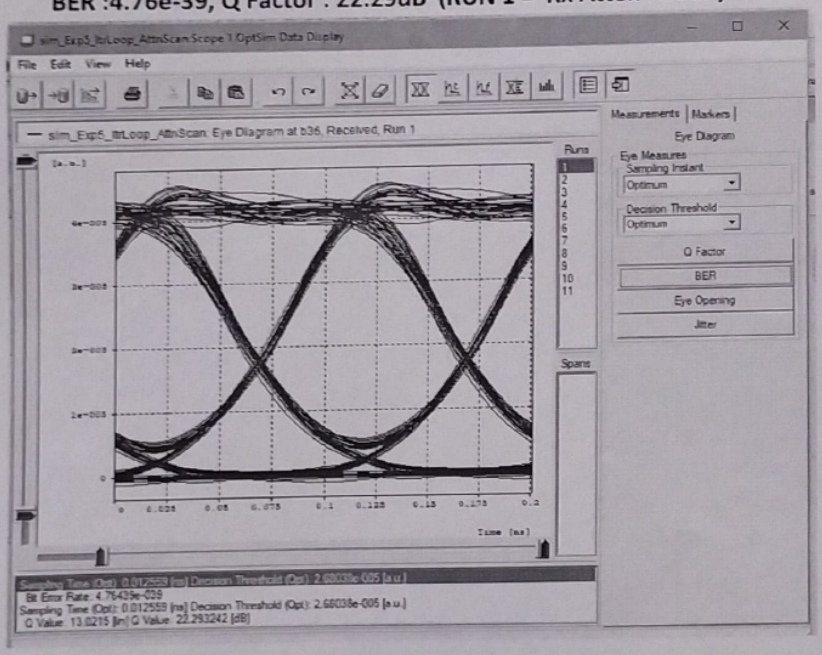


Various RUNS for different values of Rx ATtn

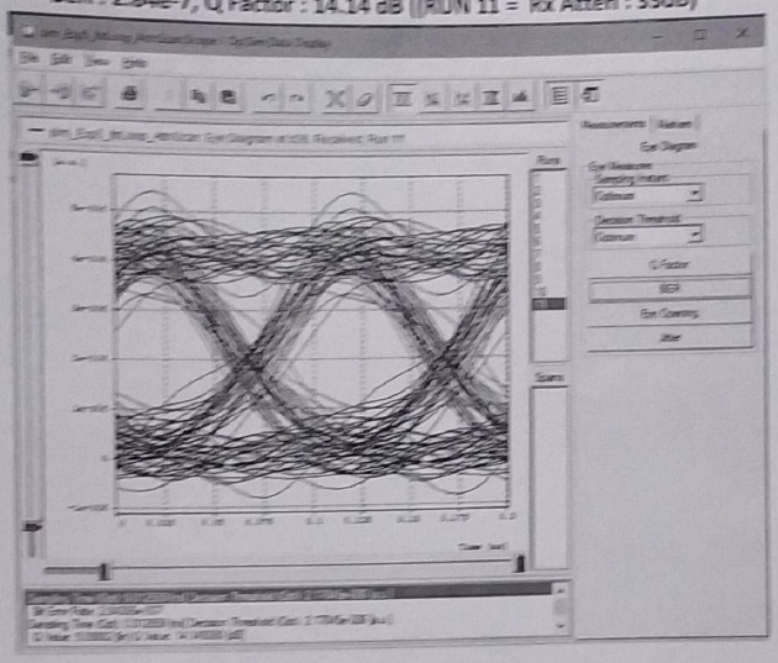


Run #	Param 1
Parameter	RX_atten
Run 1	23.0
Run 2	24.0
Run 3	25.0
Run 4	26.0
Run 5	27.0
Run 6	28.0
Run 7	29.0
Run 8	30.0
Run 9	31.0
Run 10	32.0
Run 11	33.0

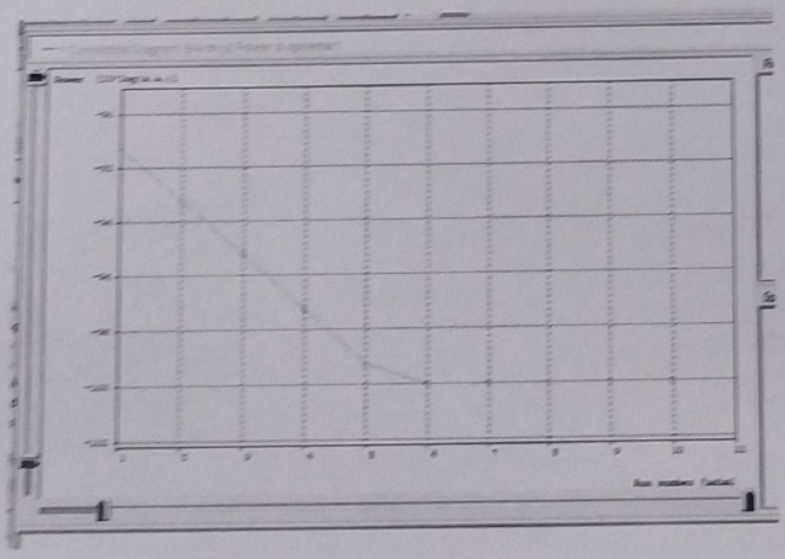
BER :4.76e-39, Q Factor : 22.29dB (RUN 1 = Rx Atten : 23dB)



BER : 2.84e-7, Q Factor : 14.14 dB ((RUN 11 = Rx Atten : 33dB)



1. Variation od received power for different values of Attenuation.



Viva Voce

Experiment 1:-

To create a network in which a 10 Gb/s NRZ optical signal is launched into 50km of standard single mode fiber with PIN photo detector as the reciever.

Q1.) What are the components of sensitivity reciever?

Components of sensitivity reciever are :- photodiode (can be PIN photo diode or Avalanche Photo Diode), before photodiode reciever can have a low pass filter as well to remove unwanted signal.

Q2.) Reason out the difference between the input and output power meter readings.

Readings of input and output optical power meter are different because the input power meter displays the value before signal transmission whereas the output power meter displays the value after signal transmission at the reciever end. The output power is less than input power due to the length of fiber and attenuation.

Q3.) What does the side lobes in recieved optical spectra signify.

The side lobes in recieved optical spectra signify noise during transmission.

Q4.) What is the performance criteria for designed optical system. Give example.

The performance criteria for designed optical system are:-

Q factor

Bit Error Rate (BER)

Q5.) Explain the eye diagram - Take a sample eye diagram and explain Amount of distortion, slope indication w.r.t. timing error, jitter,

decision point, bit time.

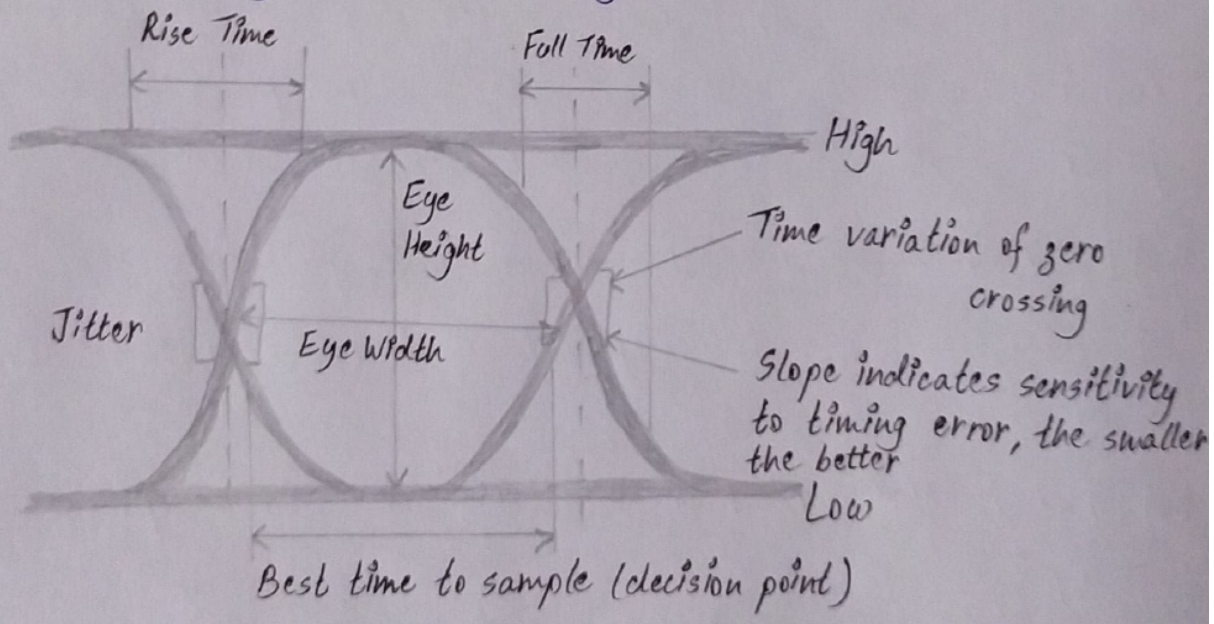
width of eye opening - time interval over which the recieved signal can be sampled without error due to ISI.

slope - determines sensitivity of the system to timing errors. Timing error increases as the slope decreases.

Jitter - Occurs due to noise in reciever and pulse distortion in optical fiber. If signal is sampled in the middle of the time interval then the amount of distortion at the threshold indicates the amount of jitter. It is the crossing point of an eye diagram.

Each point in the eye diagram corresponds to a decision point and have BER associated with it. Decision point can be defined by sampling instant and decision threshold.

Bit time - It is the measure of the horizontal opening of an eye diagram at the crossing points of the eye.



Most open part of eye = best signal to noise ratio

Experiment 2:-

To study the performance of an optical link by varying length of transmis-sion fiber using the parameter scan feature.

Q1.) Describe in a line about different components that comprises an optical transmitter.

The optical transmitter consists of following components :-

1. Data source - It is a bit generator. It is the raw input given by the user.
2. Pulse generator - It converts the data bits into pulses using NRZ or manchester line coding.
3. Carrier - It is a laser source.
4. Modulator - It is used to modulate carrier and data pulse. This signal is then sent through optical fiber.

Q2.) Can multiple parameter scans be run on in a single setup. Explain the reasons.

Yes, multiple parameter scans can be run on in a single setup. OPTSIM supports multiple simulation in one go for designing optimum parameter in system.

Q3.) What happens to the BER as the link length increases. Why?

As the link length increases, the attenuation also increases and in turn the BER increases.

Q4.) Explain the dBm to mW conversion.

$$dBm = 10 \log_{10} \frac{P}{1mW}$$

$$P = 1mW \cdot 10^{dBm/10}$$

Q5.) Discuss: At lower link lengths an increase in laser power shows no prominent difference in performance, whereas at higher distances a slight increase in power has more pronounced effects.

There are no losses in smaller length, therefore not much difference but at larger length high losses have prominent difference.

Experiment 3:-

To create 10 Gb/s optical link of standard single mode fiber using 980 nm pumped EDFA as a pre amplifier. Study of perfomance of the link with EDFA as post and inline amplifier.

Q1.) What is an optical amplifier? Why not an electric regenerator be used in an optical system?

Optical amplifier is used to amplify optical signal. It is a short section of fiber doped with lanthanoid elements. The maximum length of this short section can be 40m. An electric regenrator is not used in an optical system because for optical system the optical signal is first converted to electric signal. This conversion will lead to noise in the signal being transmitted. This degrades quality of the recieved signal.

Q2.) Discuss the placement of EDFA in an optical link.

EDFA can be placed at three different positions in an optical system.

Pre amplifier - EDFA is placed before the reciever. It is the best configuration with less BER and high Q-factor.

Post amplifier - EDFA is placed after transmitter. It acts as buffer. It is prone to more error and has poor performance as compared to preamplifier.

Inline amplifier - The fiber is divided into two parts and EDFA is placed in between those two parts. It is the worst configuration with highest BER.

Q3.) Why is preamplification better than other two configurations.

In preamplification the signal is amplified along with noise and then passed through low pass filter which filters out the noise and amplif-ied signal is fed to the reciever. This ensures that reciever recieves

noise free signal. No such arrangement is provided in post/inline amplification. Therefore, preamplification is considered as the best configuration.

Q4) What is Q-factor? Explain.

Q-factor is the measure of how noisy a pulse is. It is given by,

$$Q\text{-factor} = \frac{\text{difference of the mean value of the two signal levels}}{\text{sum of the noise standard deviation at the two signal levels.}}$$

Q5.) EDFA stands for? Mention any other optical amplifier.

EDFA stands for Eribium Doped Fiber Amplifier. Any other optical amplifier is Fiber Raman Amplifier (FRA) and Yetribium Doped Fiber Amplifier (YDFA).

Experiment-4

Study of 10 Gb/s NRZ optical signal launched into 5 spans of comprising of Dispersion Shifted Fiber (DSF) each 50 km in length followed by inline EDFA for loss compensation.

Q1.) Define span in an optical link.

A span in an optical link can be defined as a small unit the consists of fiber and an optical amplifier. Span can be repeated any number of times in an optical network.

Q2.) How is DSF different from a SMF (length, effective area, dispersion, etc.)?

	Core Effective Area	Dispersion	Wavelength
DSF	55	-2 psec/nm/km	1550nm
SMF	80	16 psec/nm/km	1300nm

Q3.) What happens when 250 km of SMF is used instead of DSF?
When 250 km of SMF is used in place of DSF the output performance is reduced with the increase in BER.

Q4.) Mention the wavelength in which we have minimum dispersion and min. attenuation in optical communication system.
1550 nm

Q5.) What type of material is used in the detector for regions 800-900 nm and 1100 – 1600 nm?
800 - 900 nm silicon
1100 - 1600 nm Indium Gallium Arsenide alloy

Experiment - 5:-

Study of 10 Gb/s NRZ optical signal launched into 5 spans of comprising of Dispersion Shifted Fiber (DSF), each 50 km in length followed by inline EDFA for loss compensation in an iteration loop. The parametric run feature used to show to vary the optical attenuation at the reciever.

Q1.) Discuss the iteration loop feature in optsim.
Iteration loop feature is used when a user wants to repeat a span 'n' number of times. By using this feature, user does not have to repeat the span. We can put the span in iteration and the number of times we want span to be repeated. This will make easier to include multiple span and the network more readable.

Q2.) What comprises the total attenuation in fiber.
The total attenuation in fiber comprises of attenuation by various components, coupling losses, splicing loss. Attenuation is also present where fiber and source are joined. The attenuation in a fiber is 0.2 dB/km.

Q3.) What is effect of attenuation on the recieved power if attenuation is increased.

As attenuation increases the power at reciever decreases. However, on increasing attenuation beyond a certain value the power at reciever becomes constant.

Q4.) Explain the difference in performance of link designed by use of 5 spans of 50 km fiber with EDFAs after each span versus a single fiber of 250 km.

It is better to use five spans of fibers of each 50 km length rather than single span of fiber of length 250 km because as length increases losses also increase. So, to compensate losses we use EDFA in middle.

Q5.) What is the use of a splitter in optical link?

Splitter is a passive component which does not disrupts the normal flow of signal. It is used to send a component of signal to a measuring device like optical power meter. One component of signal is fed to a measuring device and the other component of signal to the optical network device.

Experiment-6

Aim:- To study the performance of designed optical link with pre/post/symmetrical dispersion compensation using dispersion compensated fiber (DCF).

Measurements :- Electrical and optical spectrum analyser, electrical scope for eye diagram and Q and BER estimation, power meter

Components :-

Transmitter section: Logical sources, data source, laser source - CW Lorentz-ian lase, optical modulator - sin 2 amplitude modulator, modulator driver NRZ rectangular

Channel: SMF, Dispersion Compensation Fiber, Inline EDFA

Reciever section: Sensitivity optical reciever

Measurement components: optical power meter, optical spectrum analys-er, electrical scope.

Procedure :-

1. Create the set up using components at sample mode palette.
2. Dispersion Compensating Fiber (DCF) is introduced in various schem-es. Placement of DCF before SMF: Pre Compensation

   Placement of DCF after SMF: Post Compensation.

   Combination of pre and post compensation: Symmetrical compensa-tion
3. Optical power meters are placed before and after transmission and difference in readings are observed.
4. Observe difference in the eye diagrams in each case and notice values of Q factor and BER.

Properties :-

(a) Laser wavelength = 1550nm (193.4 THz), Power = 5dBm

(b) Data Source : PRBS Generator, Bit Rate = 10 Gb/s

(c) Electric driver : NRZ, High level = 2.5, Low level = -2.5

(d) Fiber : SMF = 120km, Loss = 0.2dB/km, Dispersion = 16 ps/nm/km

DCF = 24km, Loss = 0.2dB/km, Dispersion = -80ps/nm/km

(e) Reciever : PIN Photodiode, Sensitivity = 0.99 A/W

Theory of Dispersion Compensated fibre :- A dispersion compensating fiber (DCF) is used to compensate the cumulative dispersion in a single mode fiber and a dispersion coefficient is used to character-istic the dispersion value. The value for regular SMF is around +16 ~17 ps/nm/km at 1550nm. To manage this, DCF is used that has a negative value of dispersion coefficient, ranging from -30 to -300 ps/nm/km. As an example, the cumulative dispersion for a 10 km length of fiber will be +160~170 ps/nm/km, so to compensate for that amount of dispersion, a DCF will be added to the link with a specific and calculated fiber length aimed at reducing total dispersion close to 0 ps/nm/km. A shorter length of DCF is opted.

$$Length_{SMF} * Dispersion_{SMF} = -(Length_{DCF} * Dispersion_{DCF})$$

Eg. SMF = 120 × 16 = 1920

DCF = 24 × (-80) = -1920

Difference between different kinds of fiber

Type of fiber	Dispersion	Core Effective Area	Fiber Non-Linearity Coefficient
SMF	16 ps/nm/km	$80e^{-12}m^2$	1.266/W/km
DCF	$-\frac{L_{SMF} * D_{SMF}}{L_{DCF}}$	$67.56e^{-12}m^2$	1.8/W/km
DSF	Min; theoretically 0	$55e^{-12}m^2$	1.84/W/km

Results:-

1. Pre compensation : Q factor = 26.25 dB

BER = e^{-40}

2. Post compensation : Q factor = 27.34 dB

BER = e^{-40}

3. Symmetrical compensation : Q factor = 31.48 dB

BER = e^{-40}

Viva Questions:-

Q1. What is the range of dispersion coefficient in a DCF?

At present, the negative dispersion of commercial DCF is in the range of 100 - 150 ps/nm/km.

Q2. How is length and dispersion of DCF determined to be used in an optical link along with SMF?

The length and dispersion of DCF to be used in an optical link along with SMF can be determined using the formula:

$Length_{SMF} * Dispersion_{SMF} = -(Length_{DCF} * Dispersion_{DCF})$

The value for regular SMF is around 16 ~ 17 ps/nm/km at 1550 nm. To manage this, DCF is used that has a negative value of dispersion coefficient, ranging from -30 to -300 ps/nm/km.

Q3. Discuss the placement of DCF in an optical link. Which of the three configurations is better?

The three configurations of placement of DCF in an optical link are:
(a) Pre compensation (b) Post Compensation (c) Symmetrical Compensation

In pre compensation, DCF is placed before SMF. In post compensation, DCF is placed after SMF. In symmetrical compensation case, fiber placement follows the sequence of either SMF - DCF - DCF - SMF or DCF - SMF - SMF - DCF. Pre compensation technique of DCF is

having greatest quality factor and least bit error rate as compared to others.

Q4. How can we reduce modal dispersion?

One way to reduce modal dispersion is to use graded index fiber. Unlike the two distinct materials in a step index fibre, the graded index fiber's cladding is doped so that the refractive index gradually decreases over many layers.

With a graded index fiber, the light flows a more curved path. The high order modes spend most of the time travelling in the lower index cladding layers near the outside of the fiber. These low index core layers allow the light to travel faster than in the higher index center layers. Therefore, thier higher velocity compensates for the longer paths of these high order modes. A good waveguide design appreciably reduces modal dispersion.

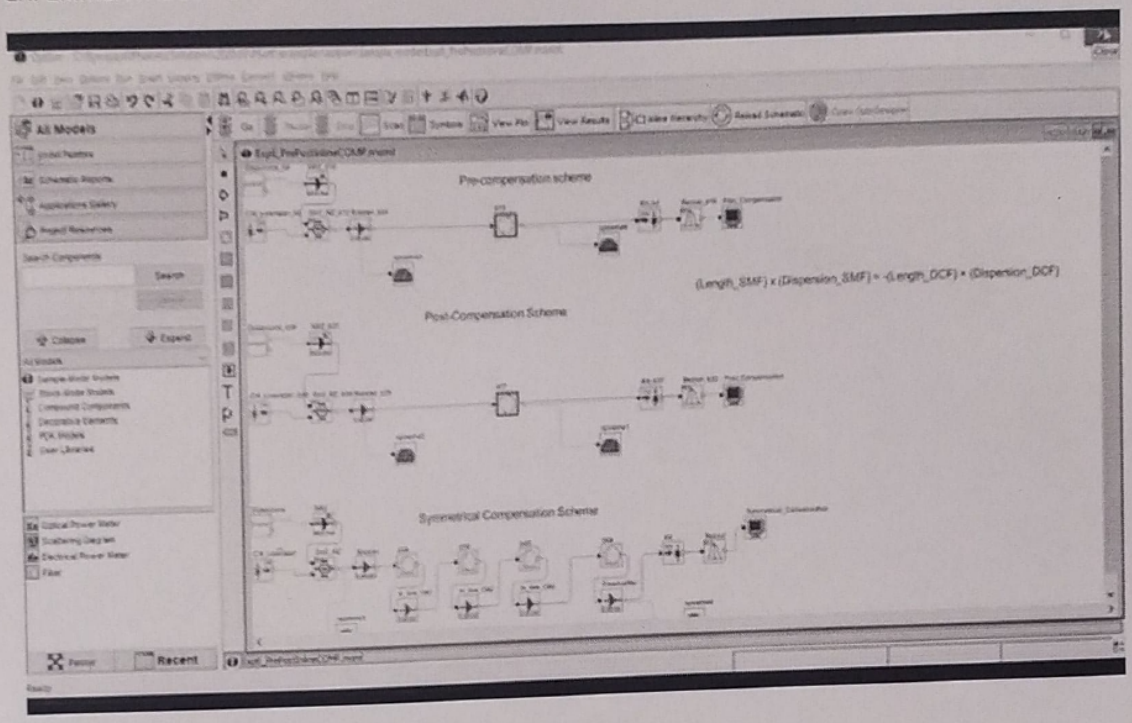
Q5. Dispersion ~~cone~~ causes intramodal interference in optical systems.

Conclusion:-

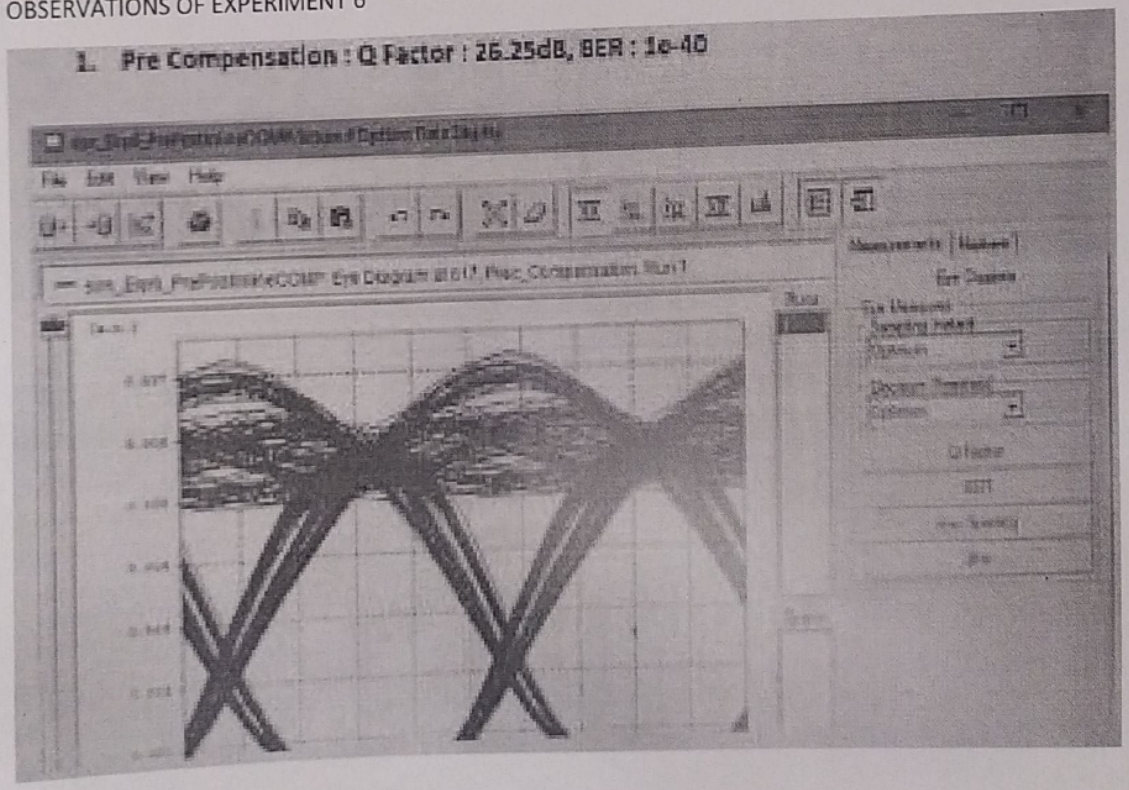
Therefore, we observe the best Q-factor is obtained by symmetrical compensation technique. Hence, out of the three compensation schemes. It is because in this technique, there has been a symmetry being maintained in thier no. of modules of single mode fiber (SMF) and DCF being used.

The eye diagram has widest eye opening in the last, i.e., symmetrical compensation technique.

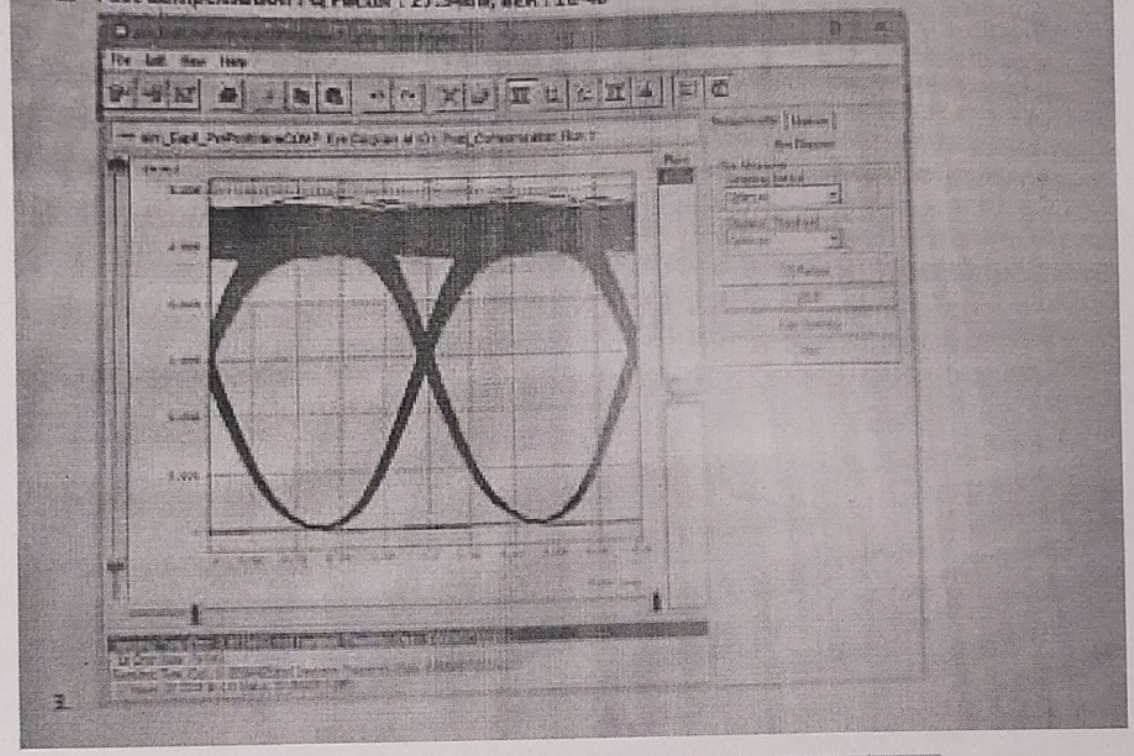
EXPERIMENTAL SET-UP OF EXPERIMENT 6



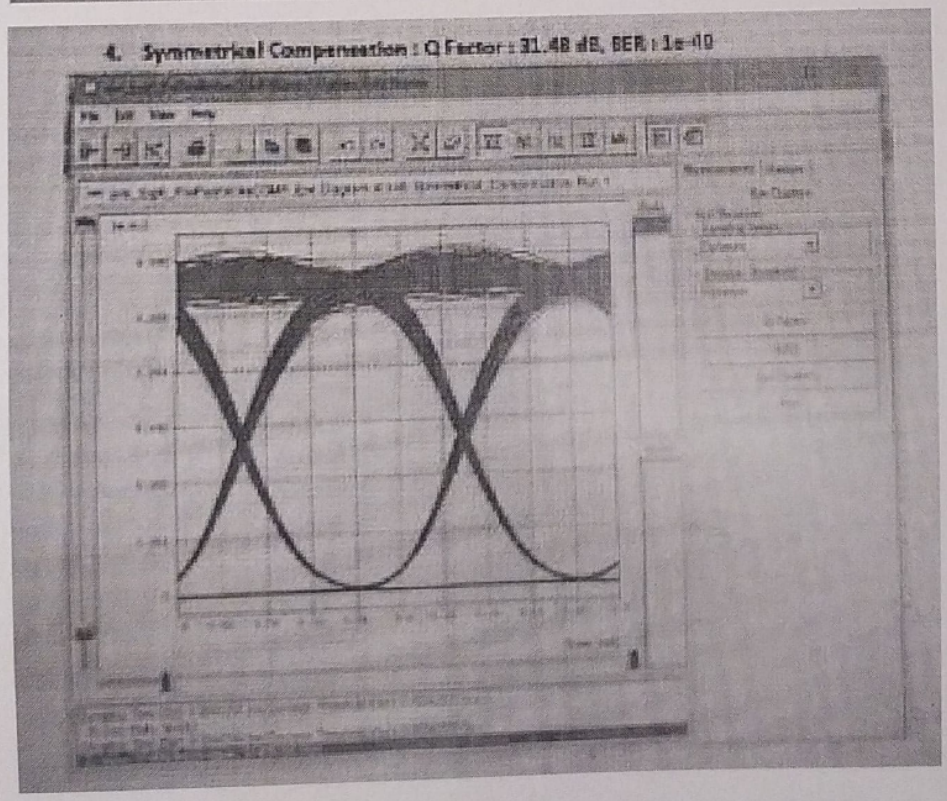
OBSERVATIONS OF EXPERIMENT 6



2. Post Compensation : Q Factor : 27.34dB, BER : 1e-40



4. Symmetrical Compensation : Q Factor : 31.48 dB, BER : 1e-10

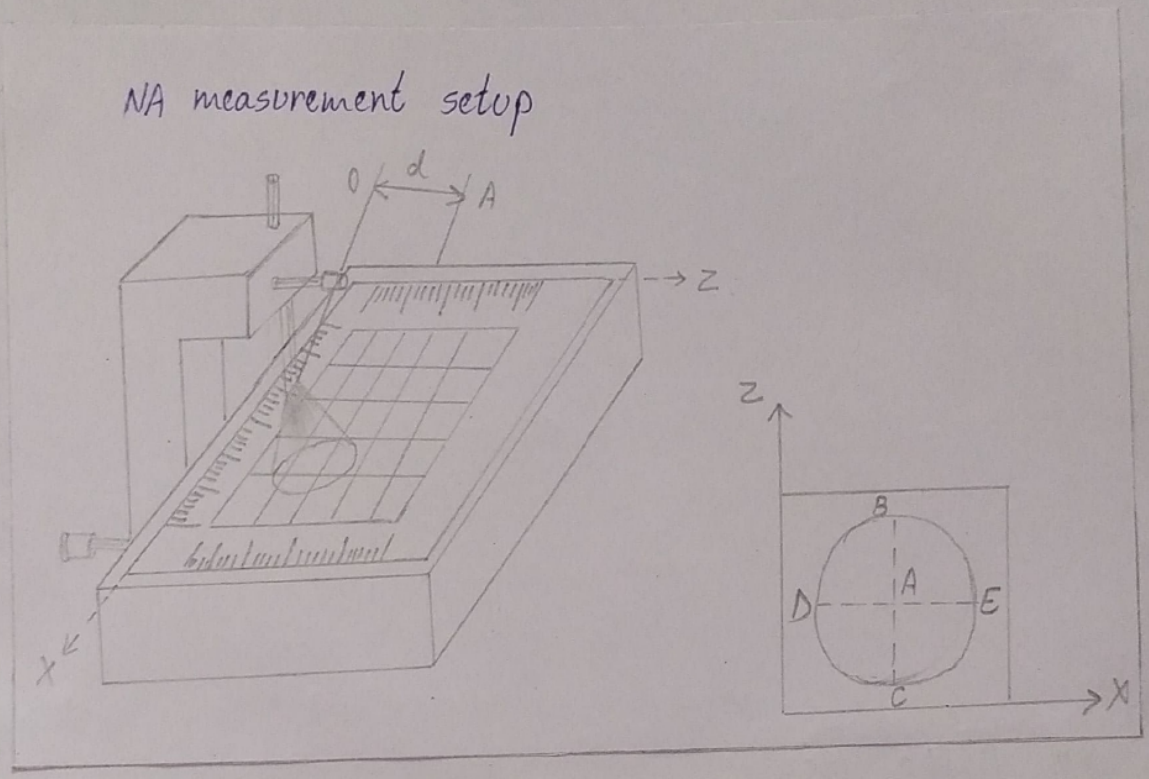


Experiment - 7

Aim :- To estimate numerical aperture of an optical fiber

Equipment required :- OFT, Numerical aperture measurement unit

Experimental Setup :-



Procedure :-

The interfaces used in the experiment are summarized in the table below :-

Identification Name	Function	Location
LED 2 650 nm	650 nm LED	Optical Tx 2 Block
S6 coded Data	Manchester coded data shorting link Post A : Coder output Post B : Input to transmitters Tx1/Tx2 electrical Posts A and B should be shorted	Manchester Coder Block
S4 Tx data	Multiplexed Transmit Data shorting link Post A : Mux output	Manchester Coder block

	Post B : Manchester coder input Posts A and B should be shorted	
S5 Tx clock	Transmitter clock shorting link Post A : Transmitter clock Post B : Manchester coder input Posts A and B should be shorted	Manchester Coder Block
JP1 clock select	Transmission clock section Posts B and A1 should be shorted	Timing and control block

1. Ensure that the shorting plugs of Tx data shorting link S4, coded data shorting link S6, and Tx clock shorting link S5 in the Manchester coder block are in position. Also ensure that the shorting plug of clock select jumper JP1 is across the posts B and A1. A TTL signal from the multiplexer should now be driving LED2 in optical Tx2 block. This experiment is best performed in a less illuminated room.
2. Ensure that the cut planes of the 1m optical fiber are perpendicular to the axis of the fiber.
3. Insert one of the fiber end into the nomerical aperture measurement unit as shown in the figure. Adjust the fiber such that its tip is 10mm from the screen.
4. Gently tighten the screw to hold the fiber firmly in place.
5. Connect the other end of the fiber to LED2 through the simpler connector. The fiber will project a circular patch of red light onto the ~~room~~ screen. Let d diameter of the circular patch of red light in two perpendicular directions (BC and DE). The mean radius of the circular patch is given by $x = \frac{DE + BC}{4}$

6. Carefully measure the distance d between the tip of the fiber and the illuminated screen (OA). The numerical aperture of the fiber is given by $NA = \sin\theta = \frac{x}{(d^2+x^2)^{1/2}}$

7. Repeat steps 3 to 6 for different values of d. Compute the arrange value of numerical aperture.

Theory:- Numerical Aperture (NA) of a fiber is a measure of the acceptance angle of light in the fiber.
Light which is launched at angles greater than this maximum acceptance angle does not get coupled to propagating modes in the fiber and therefore, does not reach the reciever at the other end of the fiber. The numerical aperture is useful in the computation of optical power coupled from an optical source to the fiber, from the fiber to a photodetector, and between two fibers.

Observations:-

S No	d (mm)	x_1 (mm)	y_1 (mm)	$x = \frac{x_1+y_1}{4}$ (mm)	$NA = \frac{x}{\sqrt{d^2+x^2}}$	Average NA
1.	1	1	1.5	0.625	0.53	
2.	2	2.5	2.75	1.312	0.548	0.52
3.	4	4	5	2.25	0.49	

Calculations:-

1. $NA_1 = \frac{1.312}{\sqrt{2^2+(1.312)^2}} = 0.548$

2. $NA_2 = \frac{2.25}{\sqrt{4^2+(2.25)^2}} = 0.49$

$NA_{avg} = \frac{0.548+0.49+0.53}{3} = 0.52$

3. $NA_3 = \frac{0.625}{\sqrt{1^2+(0.625)^2}} = 0.53$

Result:-

The numerical aperture of an optical fiber has been studied successfully. It was found that the average NA of the optical fiber used was 0.52.

Viva Questions

Q1. What is numerical aperture (NA)?

In optics, numerical aperture (NA) of an optical system is a dimensionless number that characteristics the range of angles over which the system can accept or emit light. It is the sine of the longest angle an incident ray can have for total internal reflection in the core.

Q2. How in NA related to acceptance angle of a fiber?

The acceptance angle of an optical fiber is defined as the maximum incidence angle of a light ray which can be used for injecting light into a fiber core or waveguide. It is the maximum angle of a ray hitting the fiber core which allows the incident light to be guided by the core. The sine of that acceptance angle is called the numerical aperture.

Q3. How does NA determine the performance of an optical link?

Optical fiber is one of the important elements in an optical fiber link. The performance of the link depends upon the attenuation and dispersion properties of optical fiber, which in turn are function of the input power carried by the cabled fiber. α_{max} is the maximum angle to the axis at which light may enter the fiber in order to be propagated and is referred to as the acceptance angle for the fiber.

The numerical aperture relates the acceptance angle and refractive indices of the three media involved (core, cladding and air) and is a basic descriptive characteristic of a specified optical fiber. It

represents the size or degree of openess of the input acceptance core.

Q4. The refractive index is 2.33 and the critical angle is 35°. Find the numerical aperture.

Numerical Aperture, $NA = \eta \cos\theta_c$

$\theta_c = 35°$ $\eta = 2.33$

On substituting,

$N_A = 2.33 \cos(35°) = 1.90$

Q5. The numerical aperture of a material with acceptance angle of 60° in water will be _____.

Numerical aperture $= \eta \sin\theta_a$

For water medium, $\eta = 1.33$

$NA = 1.33 \sin 60 = \frac{1.33}{2} \times \sqrt{3} = 1.15131$

Conclusion :-

The study of numerical aperture revealed that NA of a fiber is defined as the sine of the largest angle an incident ray can have for total internal reflection in the core. Rays launched outside the angle specified by a fiber's NA will excite radiation modes of a fiber. A higher core index w.r.t. cladding means larger NA. However, increasing NA causes higher scattering loss from greater concentrations of dopant. A fiber's NA can be determined by measuring the divergence angle of the light cone it emits when all its modes are excited.

Quantitatively, NA is a measure of the light gathering ability of a fiber. It also indicates how easy it is to couple light into a fiber.

Experiment-8

Aim :- To study coupling loss in an optical fiber

Components :- LEDs, photodetector

Procedure :-

1. Connect one end of the 1m fiber to LED2 and the other end to the detector PD2. Drive the LED with a 10 kHz TTL signal at post B of S6. Note the peak signal recieved at P31 and designate it as V1.
2. Now disconnect the fiber from the detector. Take the 3m fiber and connect one end to the detector PD2. The optical signal can be seen emerging from the other end of the 1m fiber.
3. Bring the free ends of the two fibers as close as possible and align them using the Fiber Assignment Unit.
4. Observe that the recieved signal at P31 varies as the free ends of the fibers are brought closer and moved apart. Note the recieved signal level with the best possible alignment and designate it as V4.
5. Using the attenuation constant value obtained in step 4, compute the coupling loss associated with the above coupling of the two fibers.

$$\eta = -10 \log\left(\frac{V_4}{V_1}\right) - \alpha'(l_3 + l_1)$$

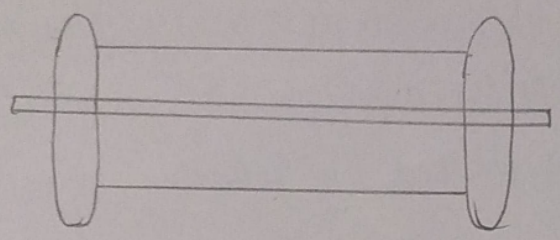
where α' is the attenuation constant in dB/m at 650 nm.

η is the coupling loss in dB.

6. Now move the two fibers a bit apart in the Fiber Alignment Unit and note the decrease in the output voltage.
7. With the two ends of the fiber are aligned as close as possible, place a drop of glycerine / isopropylene through the hole provided in the fiber Alignment Unit so as to cover the fiber ends. Note that the recieved signal now increases. Compute the coupling loss in the presence of an index matching fluid like glycerine.

8. Now try aligning the two fibers without using the fiber alingment unit. Estimate the losses as the two fibers are offset laterally and also when the two fibers are at an angle.

Experimental setup :-



COUPLING OF FIBRE

Observations :-

Parameters → Value ↓	Input	Channel (1m)	After coupling
$V_{P_x - P_x}$	96V	32V	2V
Frequency	1.28 kHz	4.4 kHz	4 kHz

Calculations :-

$$\eta = -10 \log\left(\frac{V_4}{V_1}\right) - \alpha'(l_3 + l_1)$$

$$= -10 \log\left(\frac{2}{32}\right) - 2(3+1)$$

$$= -10 \log\left(\frac{1}{16}\right) - 8$$

$$= 10 \log 16 - 8$$

$$= 4.04 \text{ dB}$$

Result :-

Coupling losses have been studied successfully. It was found that the experimental coupling loss of the optical fiber is 4.04 dB.

- Fiber separation
- Lateral misalignment
- Angular misalignment
- Core and cladding diameter mismatch

- Numerical Aperture (NA) mismatch
- Refractive index profile difference
- Poor fiber end preparation

Intrinsic coupling losses are limited by reducing fiber mismatches between the connecting fibers. This is done by procuring only fibers that meet stringent geometrical and optical specifications.
Extrinsic coupling losses are limited by following proper connection procedures.

Result:-
The coupling losses in the fiber have been studied successfully.

Viva Questions

Q1. ~~Write~~ What is coupling loss in a fiber?
Coupling loss in fiber optics refers to the power loss that occurs when coupling light from one optical device or medium to another. In optical systems, where there is a change in refractive index, coupling loss occurs when a portion of energy is reflected back into the source component.

Q2 Does coupling loss depend on the fiber length?
Yes. Coupling loss depends on the fiber length. Even for two perfectly aligned cores, where there is a gap of any significant distance between the two fibers, there will be some geometric loss due to spread of the beam.

Q3. How can coupling loss be reduced?
Intrinsic coupling losses are limited by reducing fiber mismatches between the connected fibres. This is done by procuring only fibers that meet stringent geometrical and optical specifications. Extrinsic coupling losses are limited by following proper connection procedures.

Some fiber optic components are modular devices that are designed to reduce coupling losses between components.

Q4. Define coupling efficiency.

In fiber optics, the efficiency of optical power transfer between two optical components. The transfer may take place between an active component such as an LED, and a passive component, such as an optical fiber, or between two passive components such as two optical fibers.

Coupling efficiency is usually expressed as the ratio, converted to percent of the input power, i.e., the available power from one component, to the power transfered to the other component.

Q5. Name the parameters that determine the coupling efficiency of a fiber.

The coupling efficiency is defined as a measure of amount of power emitted from an optical source that can be coupled into a fiber.

Coupling efficiency $\eta_c = P_{fiber}\ P_{source}$

where, P_{fiber} = Power coupled into the fiber

P_{source} = Power emitted from source

Conclusion :-

Ideally, optical signals coupled between fiber optic components are transmitted with no loss of light. However, there is always some type of imperfection present at fiber optic connections that causes some loss of light. It is the amount of optical power lost at fiber optic connections. Fiber to fiber connection loss is affected by intrinsic and extrinsic coupling losses. Intrinsic coupling losses are caused by inherent fiber characteristics. Extrinsic coupling lo

are caused by jointing techiques.

Experiment - 9

Aim:- To create a compound component in OPTSIM

Components :-

Transmitter : Logical source - data source, Laser - CW Lorentzian laser, Modulator driver - NRZ, rectangular, optical modulator, sin 2 amplitude modulator.

Channel : SIF

Reciever: Splitter, Bessel filter, sensitivity optical filter

Measuring components: Optical power meter, optical spectrum analyzer, electrical scope.

Measurements :- Measurements include optical spectrum, detected signal spectrum and eye diagram.

Theory :- We see that in an experiment transmitter section usually includes parts logical source, data source, laser source, modulator driver and optical modulator. If we have to repeatedly use transmitter section for multichannel system as in the case of WDM, where we have a multi wavelength so in that case, we have to use a number of these. We represent the four components of the transmitter into one merged component called compound component. So basically, compound component eases the way a design looks like.

The compound component can be created easily and used in our program. We can sit icon of our device to the compound component. We can execute compound component for all parts of fiber optics communication, i.e., channel, reciever as well as measuring component. So, we see clearly multiple blocks can be connected together and can be represented as single block known as compound component

which can be called used as many times as we want in the main project file. So, we can see that how a compound component eases our way to performing experiment and save a lot of effort as well as time. The design also becomes simplified and looks clear.

The normal function can be coined in the same way and we can take all the measurements (eye diagram, BER, Q value and eye opening).

Viva Questions

Q1. What is the need of creating a compound component?

To reduce complexity of design system

(a) Compound component symbolizes link block for many blocks

(b) We can use single block in place of multiple blocks

(c) We use four blocks of transmission as compound component (no input, only output port)

(d) Five blocks of reciever (input + output pin port)

Q2. Can you change the properties of an individual component of CC in the main file where that CC is used?

No, we cannot change the properties of an individual component of CC in the main file where that CC is used. Simulation propert-ies used to be changed in one parent file which is then reflected in the main file.

Q3. Which type of system design is complicated one design with CC or one without use of CC?

A compound component can be nested. A CC can be made from other CC. Then also it is less complicated.

Q4. Explain CC and iteration loop feature of CC.

Single component depiction of multiple components is called CC used in both transmission and recieving. Repititive feature and amplifier

combination is called iteration loop and used only in transmission

Q5. Will the CC for transmitter have an input and output port?

The CC for transmitter will only have an input port and not an output port.

Conclusion:-

A compound component can be implemented in one program file and save our time and effort. This helps simplifying complex program to simpler ones.

Experiment -10

Aim:- To study the performance of 4 NRZ signals modulated at 2.488 Gb/s, transmitted over a medium haul link with 1nm inter channel spacing. The four signals are preamplifier by an EDFA booster and is transmitted over a sequence of two DS fiber spans of 100 km each and further amplified by preamplifier.

Measurements:- Electrical and optical spectrum analyser, electrical scope for eye diagram and Q and BER estimation, electrical and optical power meter.

Components:-

Component (compound) for Tx and Rx are used

Transmitter section: Logical Sources - Data source; Laser source - CW Lorentzian Laser; Optical Modulator - Sin 2 Amplitude Modulator; Modulator Driver - NRZ rectangular.

Channel: DSF = 100 km (+ Dispersion), 100 km (- Dispersion), EDFA (Booster and Post amplifier)

Reciever section: Sensitivity optical reciever

Measurement components: Optical power meter, optical spectrum analyser, electrical scope

Properties:-

(a) Laser: Wavelength = 1548.5 nm (193.6 THz), 1549.5 nm (193.4 THz), 1550.5 nm (193.3 THz), 1551.50 nm (193.2 THz), Power = 0 dBm

(b) Data source: PRBS Generator, Bit Rate = 2.5 Gb/s

(c) Electric driver: NRZ, high level = 3.5, Low level = -1.5

(d) Fiber: DSF = 100 km + 100 km, Loss = 0.2 dB/km, Dispersion = ± 2 ps/nm/km.

(e) Reciever :- 4 Pin Photodiode (Optical fibers centralized at 4 input wavelengths), sensitivity = 0.98 A/W

Theory :- Wavelength Division Multiplexing (WDM) is a technology or technique, modulating numerous data streams, i.e., optical carrier signals of varying wavelengths (colours) of laser light, onto a single optical fiber. WDM enables multiplication of signal capacity. WDM systems are divided according to wavelength categories, generally coarse WDM (CWDM) and dense WDM (DWDM). CWDM operates with 8 channels in what is known as the 'C-Band' or 'erbium window' with wavelengths about 1550 nm. DWDM also operates in the C band but with 40 channels at 100 GHz. spacing or 80 channels at 50 GHz spacing.

Result :-

Channel	BER	Q-factor
Ch 1	$4.58e^{-21}$	19.41
Ch 2	$1.76e^{-21}$	19.52
Ch 3	$3.18e^{-20}$	19.19
Ch 4	$1.8e^{-24}$	20.09

Viva Questions

Q1. What is WDM?

Wavelength Division Multiplexing (WDM) is a technique of multiplexing multiple optical carrier signals through a single optical fiber channel by varying the wavelengths of laser lights. WDM allows communication in both the directions in the fiber cable.

Q2. Differentiate between DWDM and CWDM.

Course Wavelength Division Multiplexing (CWDM) generally operates with 8 channels where the spacing between the channels is 20 nm apart. It consumes less energy than DWDM and is less expensive. However, the capacity of the links, as well as the distance supported is lesser.

In Dense Wavelength Division Multiplexing (DWDM), the number of multiplexed channels much larger than CWDM. It is either 40 at 100 GHz spacing at 80 with 50 GHz spacing. Due to this, they can transmit the huge quantity of data through a single fiber link. DWDM is generally applied in core networks of telecommunications and cable networks. It is also used in cloud data source

Q3. WDM is an analog multiplexing technique to combine wavelength signals.

Q4. SONET and SDH stands for?

SONET - Synchronous Optical Networking

SDH - Synchronous Digital Hierarchy

Q5. What is current bit rate / WDM channel used practically?

2.5 Gbits / channel bit rate

New one increased to 40 Gbits / channel

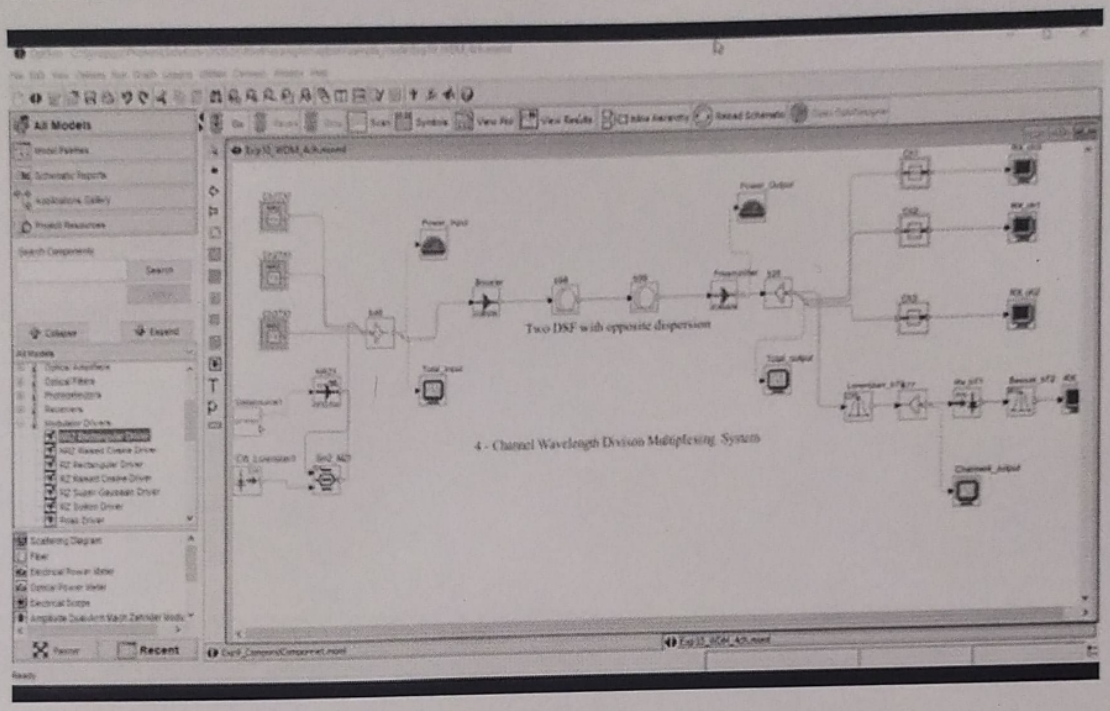
Practically, 10 Gbits $\longrightarrow$ 40 Gbits

NRZ with on off modulation scheme

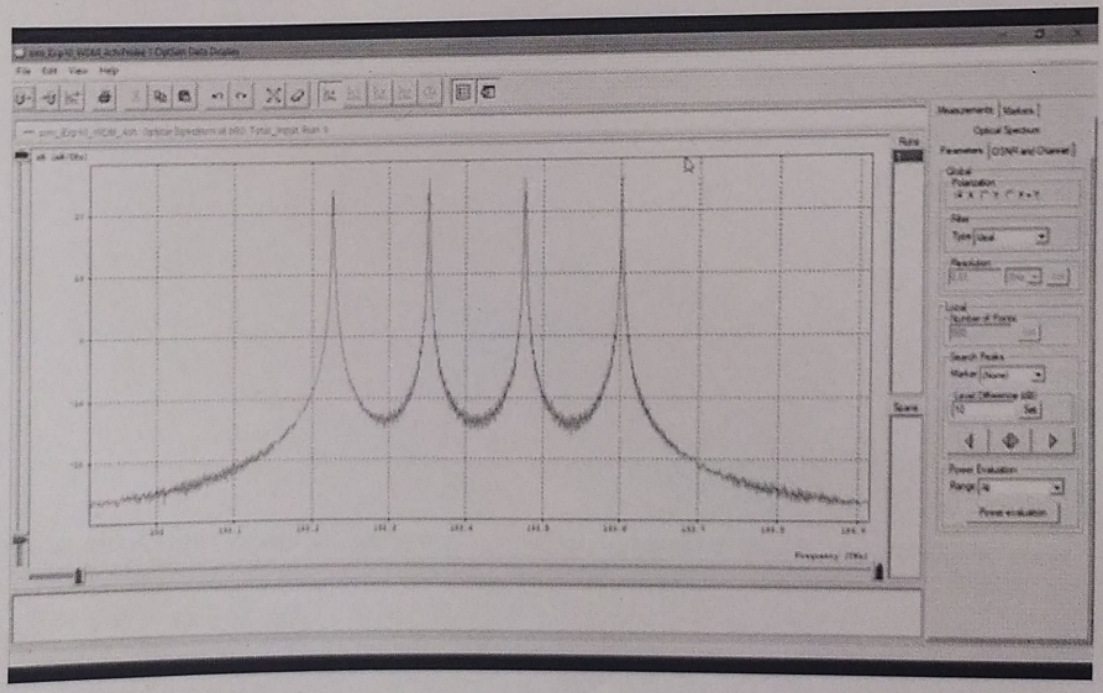
Complex modulation technique

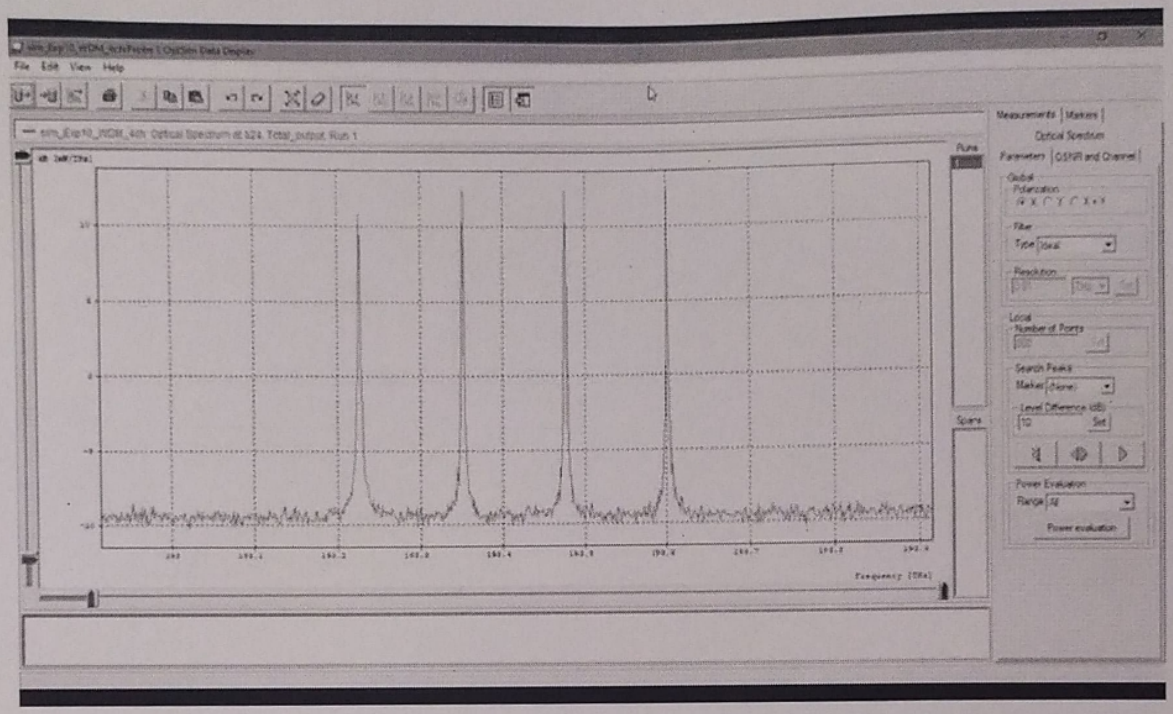
Conclusion:- We conclude that WDM enables multiplication of signal capacity. As the channel number increases, the Q factor also increases. WDM also uses a compound component in transmitter section.

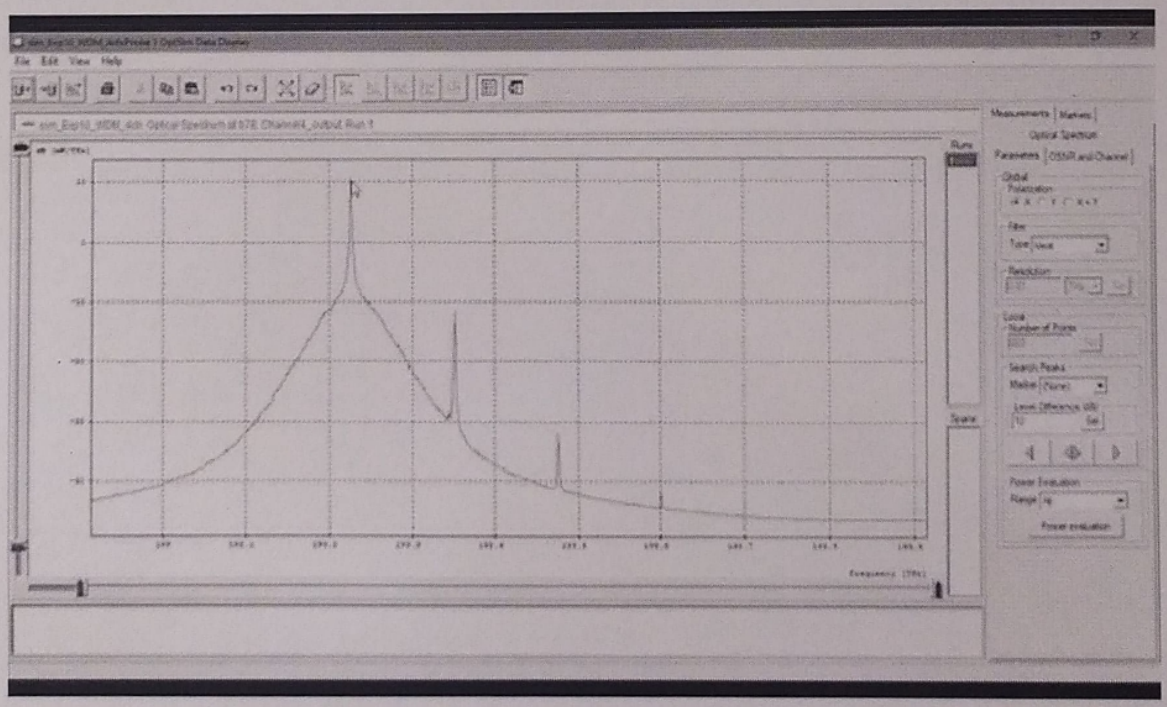
EXPERIMENTAL SET-UP OF EXPERIMENT 10

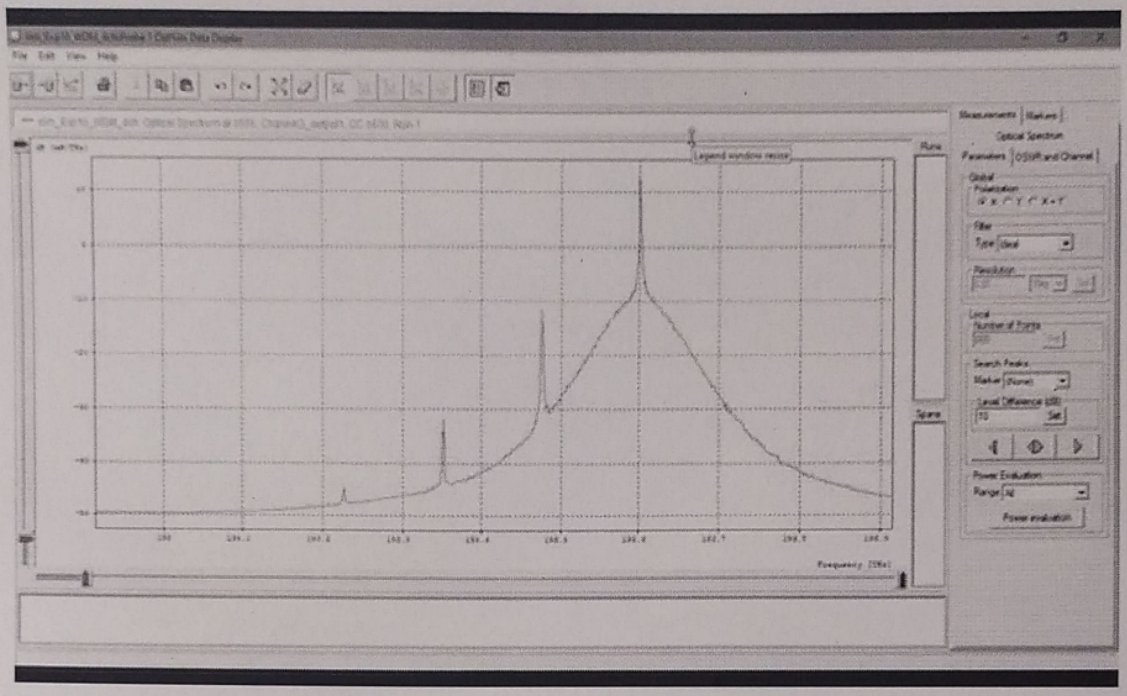


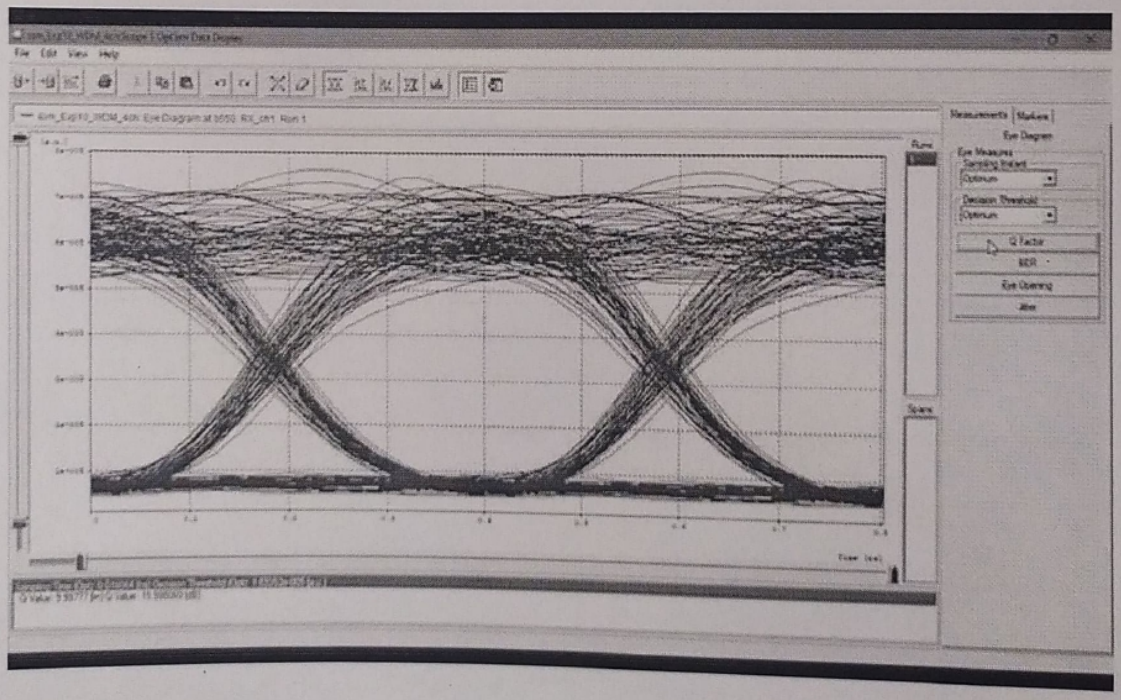
OBSERVATIONS OF EXPERIMENT 10




File Edit View Help
Measurements
Markers
Optical Spectrum
Parameters
Global
Polarization
Filter
Type
Resolution
Local
Number of Points
Search Peaks
Marker
Level Difference (dB)
Set
Power Evaluation
Range
Power evaluation
Frequency (THz)


File Edit View Help
Measurements
Markers
Optical Spectrum
Parameters
Global
Polarization
Filter
Type
Resolution
Local
Number of Points
Search Peaks
Marker
Level Difference (dB)
Set
Power Evaluation
Range
Power evaluation
Frequency (THz)


File Edit View Help
Legend window resize
Measurements
Markers
Optical Spectrum
Parameters
Global
Filter
Resolution
Local
Search Peaks
Power Evaluation
Power evaluation
Frequency (THz)


File Edit View Help
Measurements
Markers
Eye Diagram
Eye Measures
Sampling Instant
Optimum
Decision Threshold
Optimum
Q Factor
BER
Eye Opening
Time (ps)