Department of Electronics and Communication Engineering

Sub Code/Name: **BEC7L2-OPTICAL COMMUNICATION LAB**

Name : ....

Reg No : ....

Branch : ....

Year & Semester : ....

LIST OF EXPERIMENTS

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<u>**Ex No:1**</u>
<u>**Date:**</u>

V-I AND P-I CHARACTERISTICS OF LED

<u>**Aim :**</u>
To plot the VI and PI characteristics of LED operating at 850 nm wavelength and find the conversion efficiency.

<u>**Apparatus Required :**</u>
1. OFT powers supply
2. LED module
3. Optical power meter
4. Bare Fiber adapter-Plastic
5. 1.25m plastic fiber
6. 180 Ω resistor
7. Digital multimeter

<u>**Theory :**</u>
LEDs, used in optical communication have high modulation rate capability, high radiance, high reliability and emission wavelengths restricted to the near-IR spectral regions of low attenuation in fibers. The materials used are GaAs, InGaAs. The internal quantum efficiency is only 1% and external efficiency is much lower due to light emitted from semiconductor-air surface, angle of incidence, the light reflected back and absorption at the point of generation and emitting surface. Recombination of excess electrons and holes takes place whenever current is passed through the PN junction of LED. The energy released by photons results in light emission.

Precautions :

    1. Before switching on the power supply ensure that the potentiometer[R_2] is in the minimum position[Left extreme].

Tabulation :

V_f volts	I_f mA	V_{LED} volts	Power [dBm]	Power in µW [Po]

    2. me

Procedure :

1. Make the set-up as in the diagram.

2. With potentiometer in the minimum position switch on the power supply.

3. Measure the voltage across resistor R_1 and note down as V_1;

4. Measure the voltage across the LED and note it as V_{LED}; Also note down the corresponding output power in dBm from the optical power meter.

5. Calculate I_f from the formula: $I_f = V_1/180$

6. Calculate power in microwatts from the formula :

$$\text{Power}[\mu W] = 1mW * 10^{[\text{Power in dBm/10}]}$$

7. Vary the potentiometer slowly and for various values of V_1 repeat steps 3 to 6.

8. Tabulate the readings.

9. Plot the VI characteristics taking V_{LED} in the x-axis and I_f in the y-axis.

10. Plot the P-I characteristics taking I_f in the x-axis and the Power in watts in the y-axis.

11. By taking the average values of power in watts, V_{LED} and I_f and using the following formula calculate the conversion efficiency:

$$\eta = [Po*100/ (V_{LED}* I_f)] \quad \%$$

Result :

Thus the VI and PI characteristics of LED was plotted and the conversion efficiency is found as _____.

CIRCUIT DIAGRAM:

R1   R2

V_{bias}

V_{PD}

V_{LD}

L
D

U
N
I
T

Optical

Power

Meter
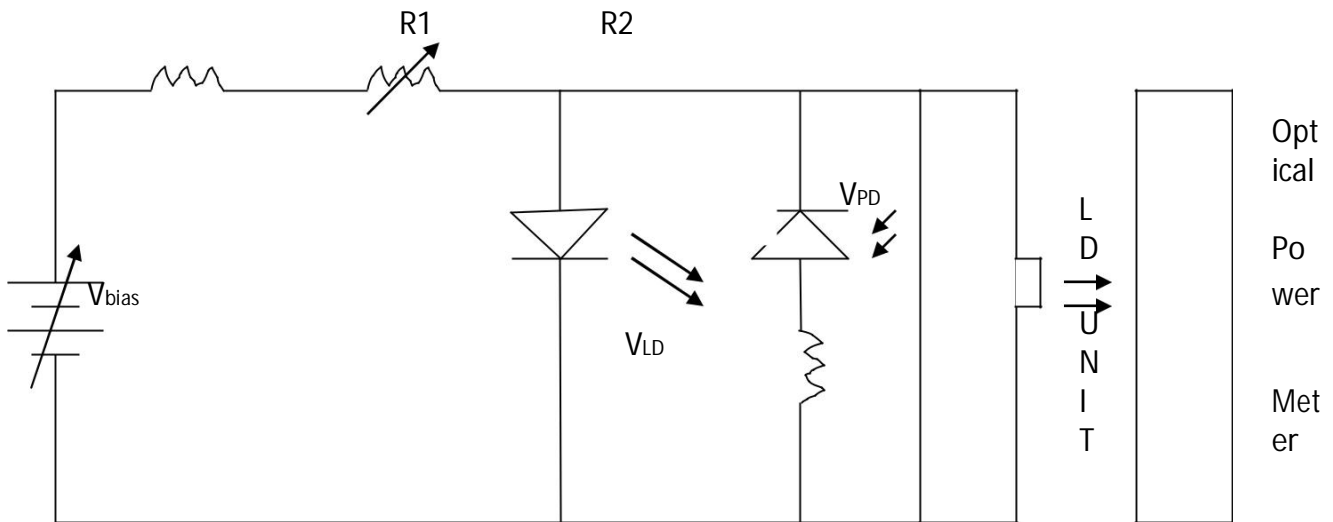
Model Graph :

P-I Characteristics

P

0

C U R R E N T [mA]
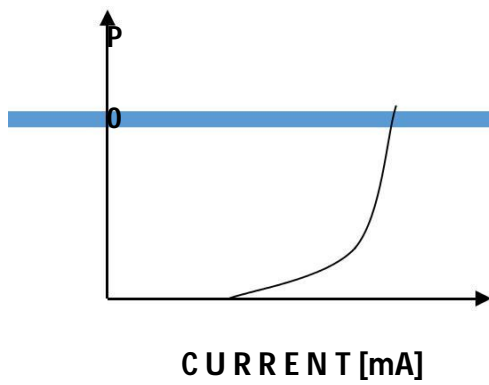
V-I Characteristics

V O L T AG E[Volts]
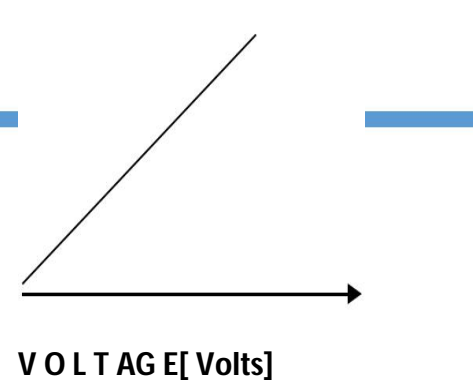
Ex No:2
Date:

CHARACTERISTICS OF PHOTODIODE

Aim: To plot distance Vs Photocurrent Characteristics of LDR and Photodiode

APPARATUS REQUIRED:

COMPONENTS REQUIRED:

S.No.	Name	Range	Type	Qty
1	R.P.S	(0-30)V		1
2	Ammeter	(0–30)mA (0–10)µ A		1
3	Voltmeter	(0–10)V		1

S.No.	Name	Range	Type	Qty
1	Photodiode			1
2	LDR	1K Ω		1 1
3	Bread Board			1
4	Wires			

Theory:

LDR
A photoresistor or light dependent resistor or cadmium sulfide (CdS) cell is a resistor hose resistance decreases with increasing incident light intensity. It can also be referred to as a photoconductor.
A photoresistor is made of a high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound lectrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance

Photodiode
A silicon photodiode is a solid state light detector that consists of a shallow diffused P-N junction with connections provided to the out side world. When the top surface is illuminated, photons of light penetrate into the silicon to a depth determined by the photon energy and are absorbed by the silicon generating electron-hole pairs.
The electron-hole pairs are free to diffuse (or wander) throughout the bulk of the

photodiode until they recombine. The average time before recombination is the "minority carrier lifetime".

At the P-N junction is a region of strong electric field called the depletion region.

It is formed by the voltage potential that exists at the P-N junction. Those light generated carriers that wander into contact with this field are swept across the junction.

If an external connection is made to both sides of the junction a photo induced current will flow as long as light falls upon the photodiode. In addition to the photocurrent, a voltage is produced across the diode. In effect, the photodiode functions exactly like a solar cell by generating a current and voltage when exposed to light.

Procedure:

Photodiode:

Connect circuit as shown in figure

Maintain a known distance between the bulb and photodiode say 5cm

Set the voltage of the bulb,vary the voltage of the diode in steps of 1 volt and note down the diode current Ir.

Repeat above procedure for VL=4V,6V,etc.

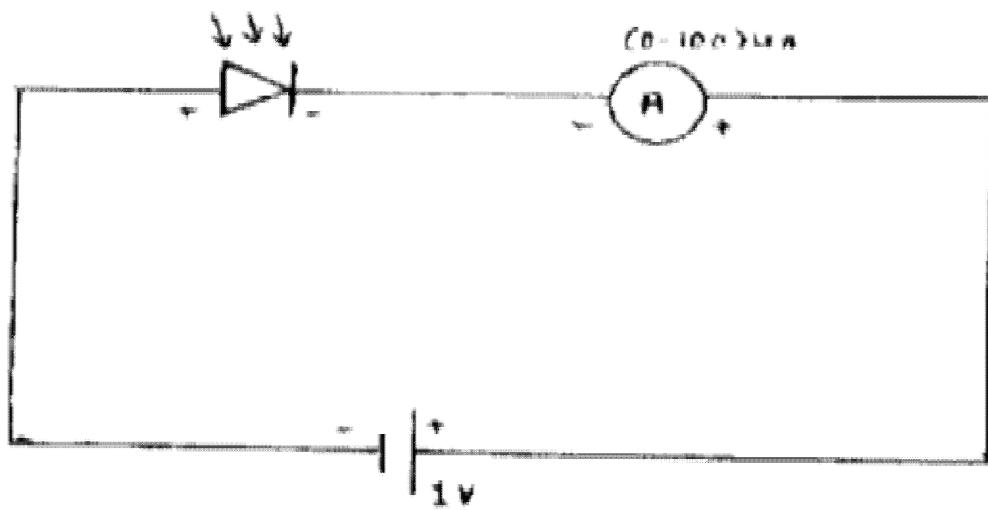Plot the graph :Vd Vs Ir for constant VL

Circuit diagram:

LDR:
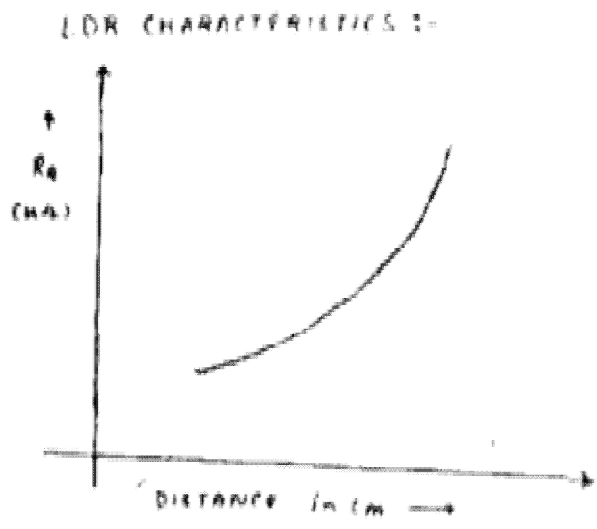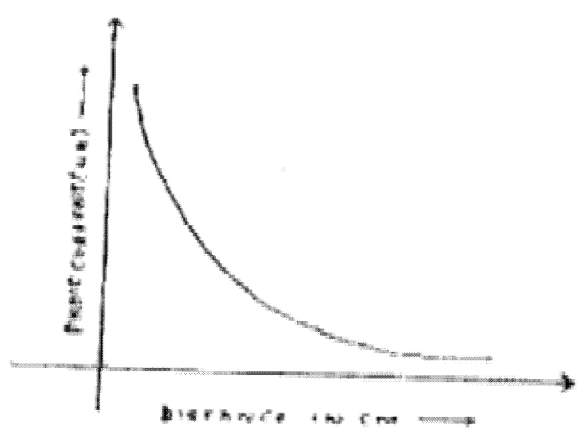

Photodiode:
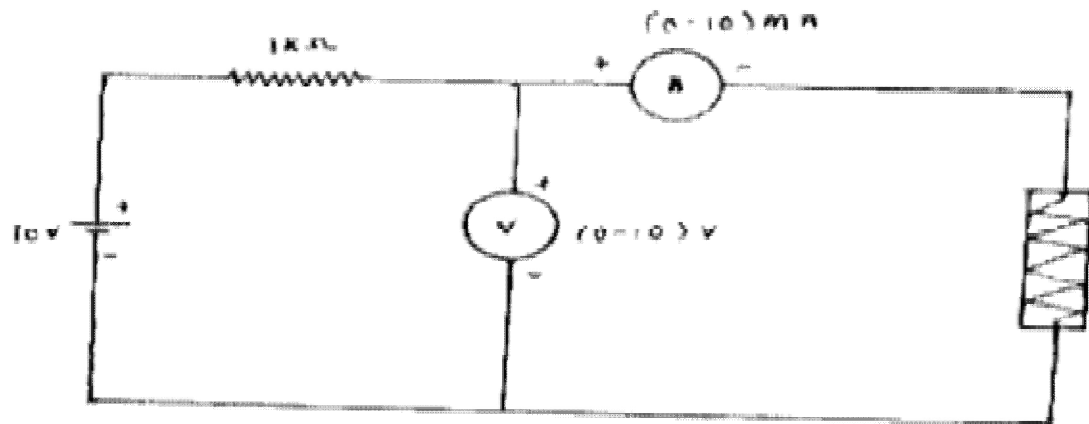
Graph:

LDR CHARACTERISTICS :-

PHOTODIODE CHARACTERISTICS :-

Tabulation

Photodiode   **Distance-constant, VL-Constant**

S. No	VD(V)	IR (mA)

Result:

The characteristics of Photodiode,to be tabulated and the graphs are plotted

Ex No:3
Date:

SETTING UP AN ANALOG LINK USING PLASTIC FIBER CABLE

Aim : To establish a fiber optic analog link and determine the bandwidth, attenuation loss, bending loss and coupling losses.

Apparatus/Components Required :

1. OFT Kit	2. CRO
3. Function Generator	4. 1m and 3m OF cables
5. 10 mm and 12 mm Mandrels	6. Jig for connecting 2 fibers

Theory :

Though optical fibers offer many advantages including very low EM interference, the signal strength decreases as light travels longer distances. This is because of the various losses including rayleigh scattering loss and increases with length.

Unless proper splicing techniques are used for connecting 2 fibers there exists considerable coupling losses due to various misalignments including axial misalignment.

Similarly there exist two kinds of bending losses viz. micro bending loss and constant radius bending losses. The former is because of the light absorbed by the water/air molecules or any irregularities which could have occurred at the time of manufacturing of the fibers. Constant radius bending losses occur because of fiber bending during cable laying.

Tabulation : **1. For Bandwidth :**

Vin = _____ Volts

Frequency [Hz]	Output Voltage [Volts]	Gain [dB]

Tabulation : **2. For Atenuation Loss :**

Vin = _____ Volts

Cable	Output voltage [Volts]
1m	$V_1=$
3m	$V_3=$

Tabulation : 3. For Bending Loss :

Cable/Bend	Output voltage V_{outbb}[Volts]	Output voltage V_{outab}[Volts]
1m / 10 mm		
1m / 12 mm		
3m / 10 mm		
3m / 12 mm		

Voutbb = output voltage without any bending

Voutab = output voltage with bend

Procedure

1.Make the connections as in the diagram. Connect the input signal from FG to I/O-1. Short I/O-1,I/O-2 and P11 _____. Connect I/O-2 and the output from P31 to the two channels of CRO. Set the switch SW8 to analog position. Adjust the gain control knob to obtain proper shape of the output signal.

2.[a] **To measure the bandwidth of the fiber :**

Note down the amplitude of input signal as Vin. Vary the frequency of the input signal from a few Hz to MHz and note down the corresponding output voltages. Tabulate the readings and calculate the gain from the formula :

Gain[dB]= 20 * log[Vout/Vin].

Plot the gain Vs frequency graph. Note down the two points which are 3 dB lower from the maximum gain on either side. Note down the corresponding frequencies as f1 and f2; then the bandwidth of the fiber is : [f2-f1]

[b] **To measure the attenuation loss in the fiber :**

Connect the 1m fiber between the Tx and Rx. Note down the input voltage as V_{in} and the output voltage as V_1.Replace the 1m fiber with 3m fiber and for the same V_{in} note down the output as V_3. Then the attenuation loss in Np/m can be calculated from :

$\alpha[Np/m]= -[1/2]* \ln[V_3/V_1]$ and $\alpha'[dB/m]= 4.343*\alpha$

Tabulation : **4. For coupling Loss :**

<center>Vin = _____ Volts</center>

Coupling	Output voltage [Volts]
Without Gap	
With 1 cm Gap	

[c] **To measure the Bending loss in the fiber :**

    1.Connect the 1m fiber between the Tx and Rx. Note down the output voltage as V_{outbb}.Take the 10mm radius mandrel and make 1 or 2 turns of the fiber on the mandrel and note down the output as V_{outab}. Now replace the 10mm mandrel with 12mm mandrel and note down the output voltage.

    2.Repeat step 1 for 3m cable.

    3. Calculate the bending loss from the formula:

        Bending Loss[dB]= $20*log[V_{outbb}/V_{outab}]$

[d] **To measure the Coupling loss in the fiber :**

    Connect one end of the 1m fiber to the Tx and one end of the 3m fiber to the Rx. Connect the remaining 2 end together using the Jig

making the ends to touch each other. Note down the input and output voltages.

With the same input voltage, introduce 1cm gap between the fiber ends connected in the jig and note down the output voltage. Calculate the coupling losses without gap and with 1cm gap using the formula:

η= 20*log [Vin / Vout] – α'[L1+L2] where α'= 4.343α and L1= 1m and L2= 3m

Result :

The fiber optic link for analog transmission has been set up and the following were determined:

Bandwidth of the analog link :		
Attenuation loss in Np/m:		
Attenuation loss in dB/m:		
Coupling loss without Gap in dB:		
Coupling loss with 1cm Gap in dB:		
================================	1m cable	3m cable
Bending loss with 10mm radius bend[dB]		
Bending loss with 12mm radius bend[dB]		

Ex No:4
Date:

SETTING UP FIBER OPTIC DIGITAL LINK

OBJECTIVE:

The objective of this experiment is to study a 650 nm fiber optic digital link. In this experiment, we will study a relationship between the input signal and the received signal.
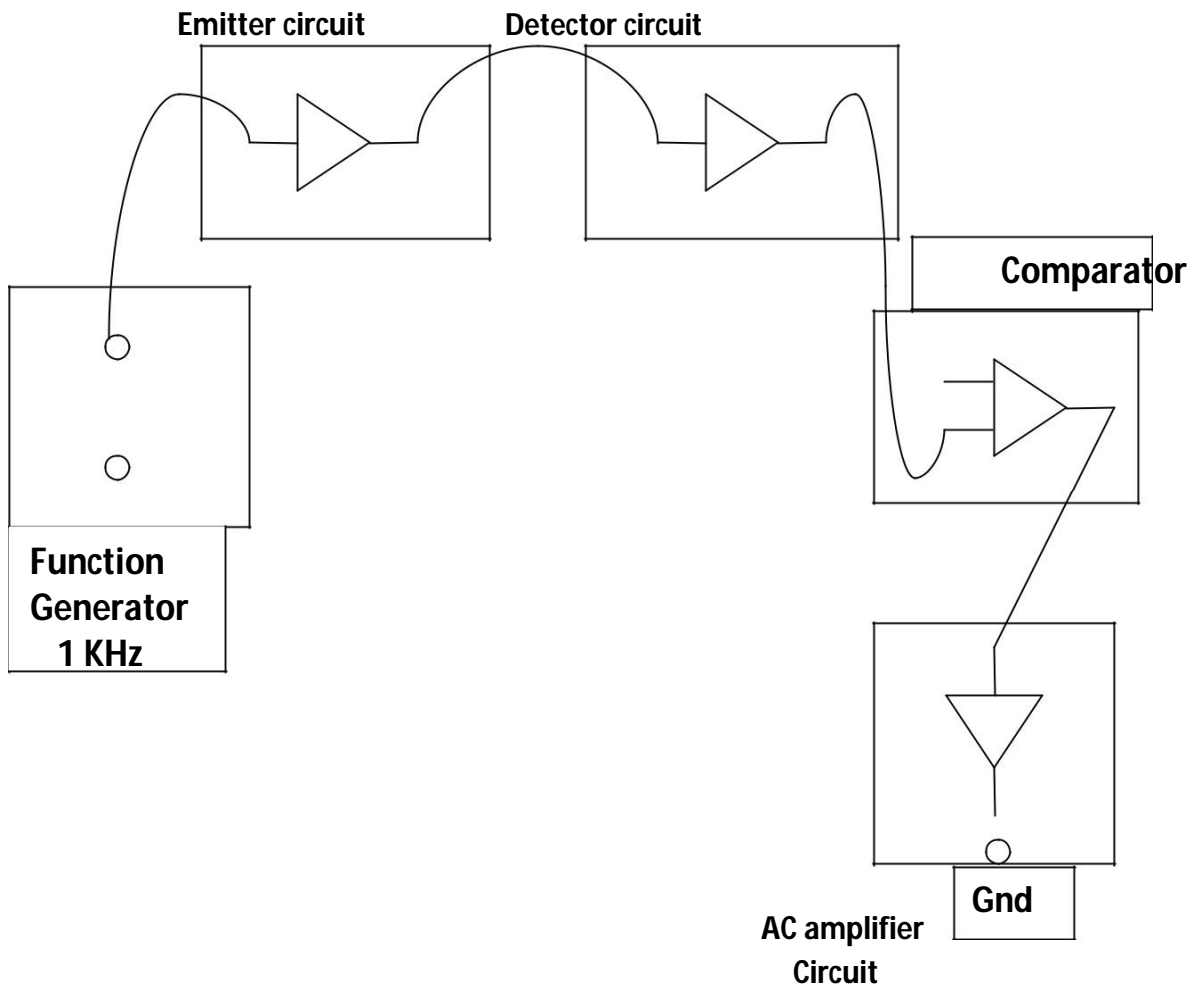
PROCEDURE:

1. Connect the power supply to the board.
2. Ensure that all switch faults are OFF.
3. Make the following connections.
   a. Connect the function generator 1 KHz square wave output to the emitter 1's input.
   b. Connect the fiber optic cable between the emitter's output and detector's input.
   c. Connect detector 1's output to the comparator 1's input.
   d. Connect comparator 1's output to AC amplifier 1's input.
4. On the board switch emitter 1's driver to digital mode.
5. Switch ON the power.
6. Monitor both the inputs to comparator 1 (tp 13 and tp 14). Slowly adjust the comparator bias. Reset until DC level on the input (tp 13) lies midway between the high and low level of the signal on positive input (tp 14).
7. Observe the input to emitter (tp 5) with output from AC amplifier 1 (tp 28) and note that the two signals are same.

RESULT:

Thus the relationship between input and output waves was obtained.

Frequency (KHz) =

SETTING UP FIBER OPTIC DIGITAL LINK

Emitter circuit   **Detector circuit**

Comparator

**Function
Generator
1 KHz**

**AC amplifier
Circuit**   **Gnd**

OBSERVATION

Input Voltage (V)	Output Voltage (V)	Time (ms)

:

_____

Ex No:7
Date

<div align="center">NUMERICAL APERTURE FOR A PLASTIC FIBER</div>

AIM:

To measure the numerical aperture of the plastic fiber provided with kit using 660 nm wavelength LED.

APPARATUS REQUIRED:

S.No.	Name of the Equipments	Quantity
1.	Link – B **Advance** Fiber Optic Communication Trainer Kit	1
2.	Power Supply	1
3.	Fiber Optic Cable (Plastic)	1 meter
4.	Numerical Aperture measurement Jig	1
5.	Steel Ruler	1
6.	Patch Chords	Required

THEORY:

Numerical aperture refers to the maximum angle at the light incident on the fiber end is totally internal reflected and is transmitted properly along the fiber. The cone formed by the rotation of this angle along the axis of the fiber is the cone of acceptance of fiber. The light ray should strike the fiber end within its cone of acceptance; else it is refracted out of the fiber core.

Numerical aperture is the measure of the power launching efficiently of an optical fiber. When N.A. is small, then the light available from various directions from the source, only a portion of light is accepted by an optical fiber and the remaining is rejected.

OBSERVATION:

d (mm)	MR (mm)	PN (mm)	r (mm)	NA

$$r = \frac{(MR+PN)}{4}$$

$$NA = \sin\theta_{max} = \frac{r}{\sqrt{d^2 + r^2}}$$

PROCEDURE:

1. Make connections as shown in figure. Connect the power supply cables with proper polarity to Link – B Kit. While connecting this, ensure that the power supply is OFF.
2. Keep Intensity control pot **P2** towards **minimum** position.
3. Keep Bias control pot **P1** fully clockwise position.
4. Switch ON the power supply.

5. Slightly unscrew the cap of SFH 756V (660) nm. Do not remove the cap from the connector. Once the cap is loosened, insert the 1 Meter Fiber into the cap. Now tighten the cap by screwing it back.

6. Insert the other end of the Fiber into the numerical aperture measurement jig. Adjust the fiber such that its cut face is perpendicular to the axis of the Fiber.

7. Keep the distance of about 5mm between the fiber tip and the screen. Gently tighten the screw and thus fix the fiber in the place.

8. Increase the intensity pot **P2** to get bright red light circular patch.

9. Now observe the illuminated circular patch of light on the screen.

10. Measure exactly the distance **d** and also the vertical and horizontal diameters **MR** and **PN** as indicated in the Figure.

11. Mean radius is calculated using the following formula

$$r = (MR+PN)/4.$$

12. Find the numerical aperture of the fiber using the formula

$$NA = \sin \theta_{max} = \frac{r}{\sqrt{d^2 + r^2}}$$

Where θ_{max} is the maximum angle at which the light incident is properly transmitted through the fiber.

RESULT :

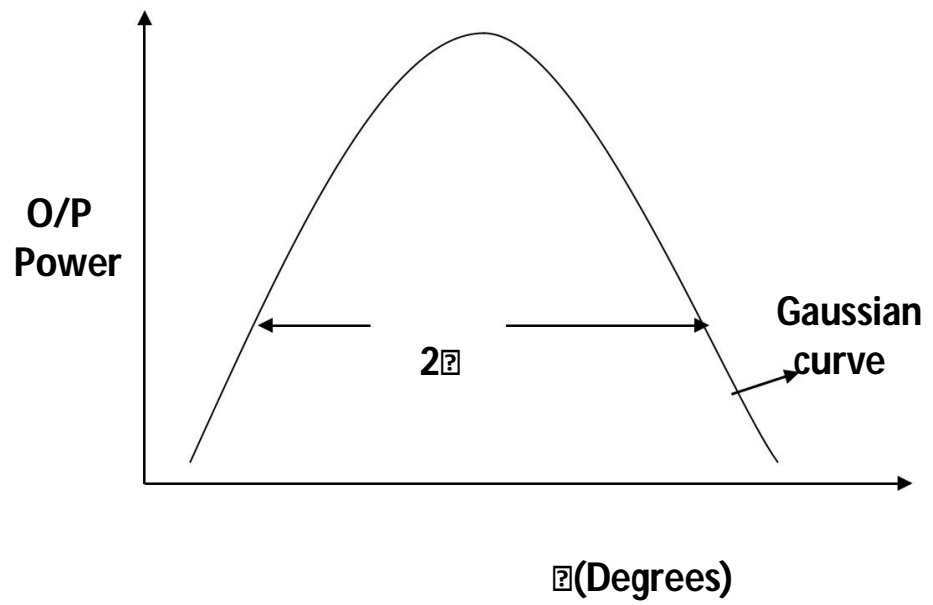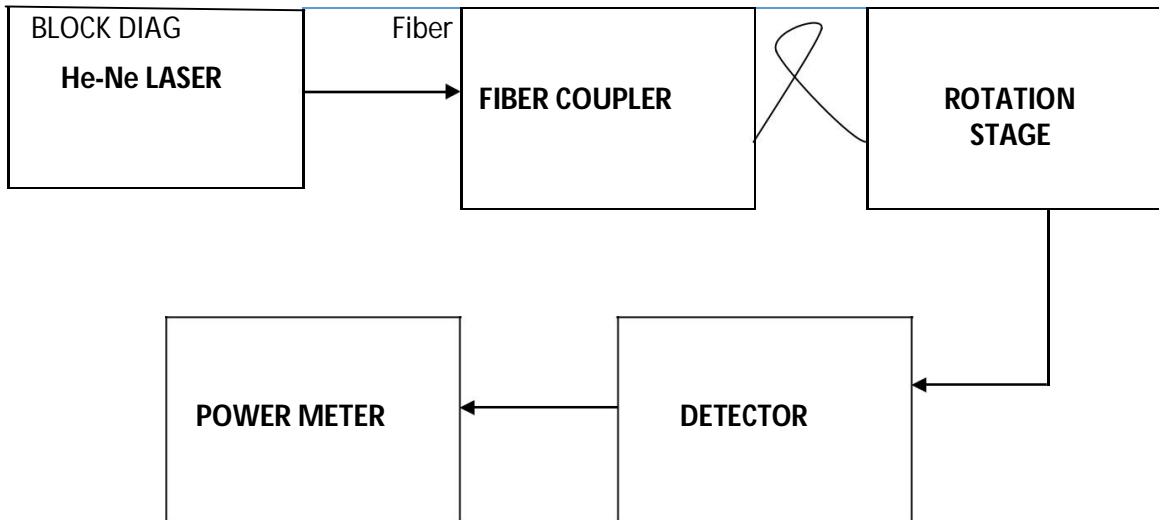Thus Numerical aperture of the plastic fiber provided with kit using 660 nm wavelength LED was measured as _____.

BLOCK DIAG

He-Ne LASER → Fiber → **FIBER COUPLER** → **ROTATION STAGE**

ROTATION STAGE → **DETECTOR** → **POWER METER**

O/P Power

2⏁

Gaussian curve

⏁(Degrees)

Figure: Field Distribution

Ex No: 12
Date

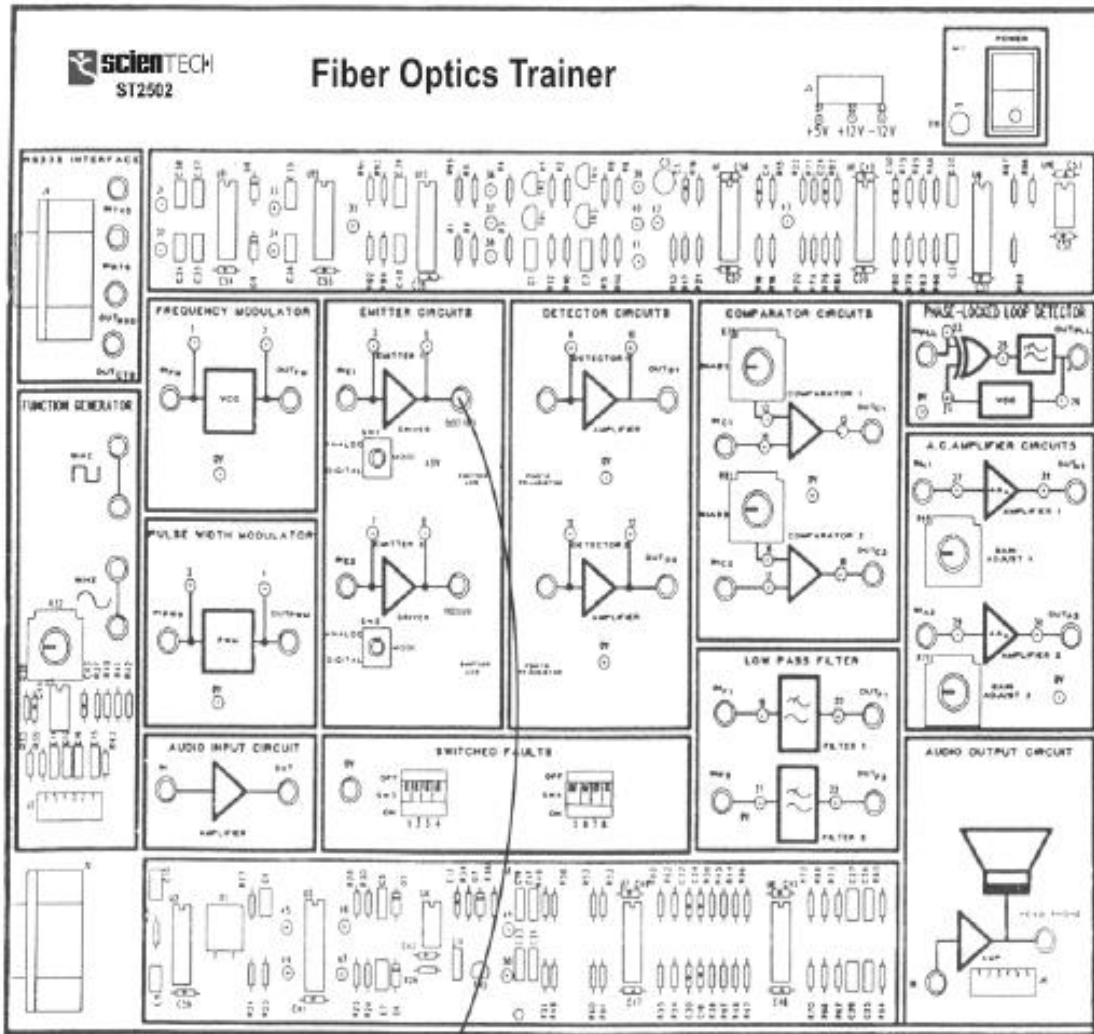## NUMERICAL APERTURE FOR OPTICAL GLASS FIBER
(MULTIMODE / SINGLE MODE)

Objective: To measurement of the Numerical Aperture (NA) of the fiber.

Apparatus Required:

3. ST2502 trainer with power supply cord

4. Optical Fiber cable.

5. Numerical Aperture measurement Jig/Paper & Scale.

Fig.8.1 Connection diagram on ST502

Theory:

The numerical aperture refers to maximum angle at which the incident on fiber end is totally internally reflected and is transmitted along the fiber. The cone formed by rotation of this angle along
the axis of the fiber is the cone of acceptance of fiber. if light ray should strike the fiber end within this cone of acceptance it will be transmitted properly else it is refracted out of fiber.

NA= $n \sin \theta_{max} = \sqrt{n_{core}^2 - n_{clad}^2}$,
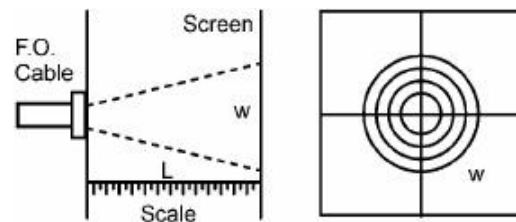
Procedure:

7. Connect the Power supply cord to mains supply and to the trainer ST2502.

8. Connect the frequency generator's 1 KHz sine wave output to input of emitter 1 circuit. Adjust its amplitude at 5Vpp.

9. Connect one end of fiber cable to the output socket of emitter 1 circuit and the other end to the numerical aperture measurement jig. Hold the white screen facing the fiber such that its cut face is perpendicular to the axis of the fiber.

10.   Hold fiber vertically at a suitable distance to make the red spot .

11.   Record the distance of screen from the fiber end L and note the diameter W of the spot.

Compute the numerical aperture from the formula given below-

NA= (W/2) / √(W/2)^2+L^2

Result : The N.A. of optical glass fiber measured .

Ex No:13
Date:

COUPLING LOSS IN OPTICAL GLASS FIBER(MULTIMODE / SINGLE MODE FIBER)

Aim:

To observe the attenuation & coupling loss in optical fiber.

EQUIPMENT:-

- power supply psu or ps1
- Testing module MCM-40
- Multimeter

THEORY:-

When the light crosses an absorbing medium, as in the case of optical fiber, the luminous energy decrease as distance increases. The loss in a fiber length **(attenuation)** is expressed by the ratio between the power entering one end of the fiber (P_{IN}) and power coming out from the opposite end (Pout). Attenuation is normally measured in decibel:

$$Att (dB) = 10 \log (P_{out}/P_{in})$$

It can ranges fro some db/**m** for plastic fiber ,to fraction of db/km for glass fibers.

The attenuation of the light signal due to the fibers depends on the wave length and on the material which the fiber has been constructed with . In glass fiber the main causes of attenuation are the absorption losses and the scattering losses. Combining these losses lead to plotting the intrinsic attenuation curve like that shown in the fig 1 whereas the fig2 shown the attenuation curve of a plastic fiber. Following losses leads to attenuation

Absorption loss: When the light photons have a certain value of energy, the atoms of glass of the core (SiO_2) absorb a part of this energy. This phenomenon depends on wavelength and there are two different absorption zones, occurring in the infrared spectrum and in the ultra violet spectrum. Furthermore, during the chemical process of glass manufacturing, various metallic impurities are trapped in the core, among these impurities there are also some ions OH- which provoke absorption peaks at discrete value of wavelength.

Scattering loss: They are due to the granular structure (at microscopic level) of the material which the fiber is constructed with. This structure includes some scattering centers which are material point that scatter the radiation in all directions, even backwards this phenomenon is called **Rayleigh scattering** or material scattering.

Other losses : In an optical fiber link, other can be due to too narrow loops in the path of the optical cable (Bending losses), or to junction of more lengths of fiber. Of course they are not intrinsic losses of the fiber, but they depend on cable laying.

PROCEDURE:-

Attenuation of the fiber with increase in length
- power the module
- Disconnect the jumper j13 and connect j7c-j9b-j10b-j11-j12b, so that the circuit can be arranged as it is shown in fig 1. This configuration includes the LED and the photodiode at 660 nm; moreover an alternating data signal (0/1) is applied to the input of the digital driver
- connect the LED to the photodiode through the cable # 1,ST-St adapter and cable 6
- set the bias trimmer (p4) to its intermediate position. connect j15b and observe the waveform in TP24 (voltage detected by the assembly "photodiode +Tran impedance amplifier") on the oscilloscope
- Record the amplitude v_{out1} of the square wave detected .
- Replace the cable # 1(plastic fiber of 1.5m) with the cable # 2(plastic fiber of 5 m) and measure the new amplitude v_{out2} of the received signal, in TP24.
- Calculate $v_{out2}/ v_{out1=}$.............................

Coupling and bending Losses
- keep the same condition of the previous test (LED and photodiode at 660 nm connected through the cable # 2)
- observe the waveform in TP24, on the oscilloscope
- looser the fiber connector inserted in the ST-ST adapter and gradually move it away from the same adapter (and hence from the second ST connector inserted in the adapter)
- note that the amplitude of the receive signal decrease as the connection is loosen, it also depends on the angle at which the connector of the source and of the detector are connected.
- Bend the fiber and observe the wave form it will be observed that for sharp bends the wave form is more attenuated as the bending losses increases.

Attenuation of the fiber as a function of wavelength
- remove the jumper j12b and connect the j13b, in order to use the LED and the photodiode at 820nm
- connect the LED 1 to the photodiode PD1 through the cable #1 (plastic fiber of 1.5m)
- connect j15a and observe the waveform in TP23
- record the amplitude v_{out3} of the square wave detected
- replace the cable #1 (plastic fiber of 1.5 m) with the cable #2 (plastic fiber of 5 m) and measure the new amplitude v_{out4} of the signal received, in TP23
- Calculate v_{out4}/ v_{out3} =..................

RESULT:-
- It has been observed that the coupling loss increases as the cable length increases
- The plastic fiber cable offer greater attenuation at 820nm then on 660nm

Ex No: 14
Date:

<div align="center">

BIT ERROR RATE MEASUREMENT

</div>

AIM:

To Measure bit error rate.

APPARATUS REQUIRED:

S.No.	Name of the Equipments	Quantity
7.	Link – B **Advance** Fiber Optic Communication Trainer Kit	1
8.	Power Supply	1
9.	Fiber Optic Cable (Plastic)	1 meter
10.	20 MHz Dual channel Oscilloscope	1
11.	Probes, Patch Chords	Required

THEORY:

BIT ERROR RATE:

In telecommunication transmission, the bit error rate (BER) is a Ratio of bits that have errors relative to the total number of bits received in a transmission. The BER is an indication of how often a packet of other data unit has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent.

OBSERVATION:

Tb = 320Kbits

S.No:	Error Counter	Eb	BER
1.			
2.			
3.			
4.			
5.			

BER = Eb/Tb

Where   Eb – Errored bits

Tb – Total bits Transmitted in a period of time t seconds.

Measuring Bit Error Rate:

A BERT (bit error rate tester) is a procedure or device that measures the BER for a given transmission. The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits transmitted.

BER = (Bits in error) / (Total bits transmitted)

PROCEDURE:

1. Make connections as shown in figure. Connect the power supply cables with proper polarity to Link – B Kit. While connecting this, ensure that the power supply is OFF.

2. Keep **PRBS** switch **SW7** as shown in figure to generate PRBS signal.

3. Keep switch **SW8** towards **TX** position.

4. Keep switch **SW9** towards **TX1** position.

5. Keep the switch **SW10** at fiber optic receiver output to **TTL** position.

6. Select PRBS generator clock at 32 KHz by keeping jumper **JP4** at **32K** position.

7. Keep Jumper **JP5** towards **+5V** position.

8. Keep Jumper **JP6** shorted.

9. Keep Jumper **JP8** towards **Pulse** position.

10. Switch ON the power supply.

11. Connect the post **DATA OUT** of PRBS Generator to the **IN** post of digital buffer.

12. Connect **OUT** post of digital buffer to **TX IN** post.

13. Slightly unscrew the cap of SFH 756V (660) nm. Do not remove the cap from the connector. Once the cap is loosened, insert the one Meter Fiber into the cap. Now tighten the cap by screwing it back.

14. Slightly unscrew the cap of RX1 Photo Transistor with TTL logic output SFH 551V. Do not remove the cap from the connector. Once the cap is loosened, insert the other end of fiber into the cap. Now tighten the cap by screwing it back.

15. Connect detected signal **TTL OUT** to Bit Error Rate event counter **DATA IN** post & post **IN** of Noise Source.

16. Connect post **OUT** of Noise Source to post **RXDATA IN** of Bit Error Rate event counter.

17. Connect post **CLK OUT** of PRBS Generator to post **CLK IN** of Bit Error Rate event counter.

18. Press Switch **SW 11** to start counter.

19. Vary pot **P3** for **Noise Level** to observe effect of noise level on the error count.

20. Observe the Error Count LED's for the error count in received signal in time 10 seconds as shown in figure.
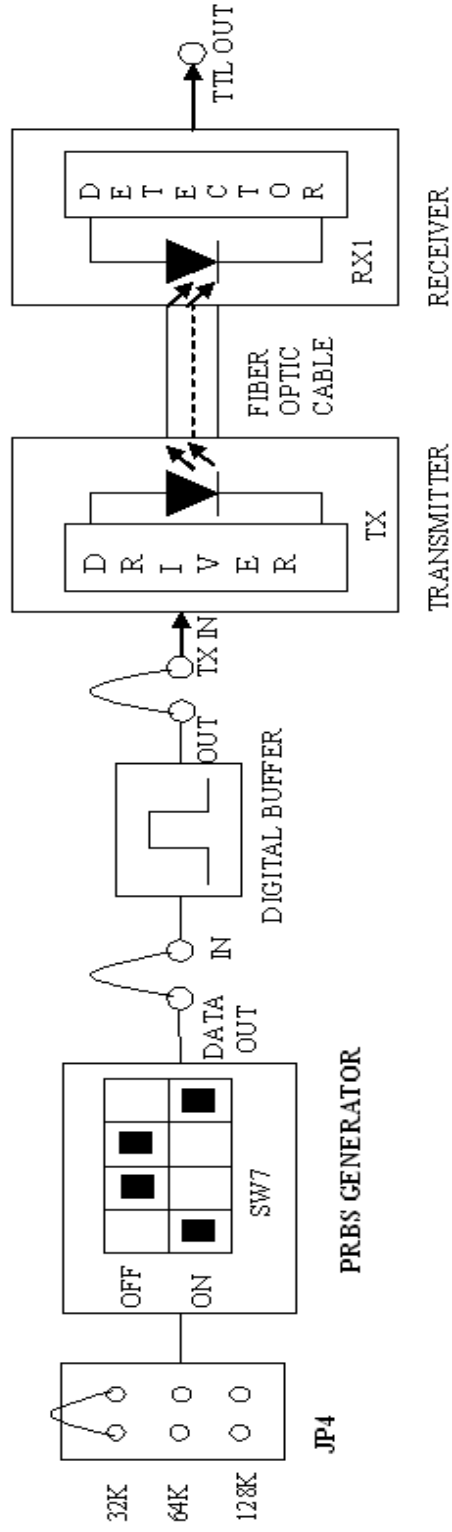
RESULT:

Thus Bit error rate for given Sequence was measured.

REVIEW QUESTIONS:

1. Define bit error rate (BER)
2. What are the typical error rates for optical fiber telecommunication systems?
3. Why transimpedance amplifier is commonly used in optical communication receiver?
4. What devices are used as pre-amplifiers for Giga bits/sec. data rate?

BLOCK DIAGRAM:

JUMPER SETTING DIAGRAM: