LABORATORY MANUAL

COMMUNICATION SYSTEMS LAB (S7 T)

OPTICAL COMMUNICATION LAB

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

COLLEGE OF ENGINEERING

TRIVANDRUM

2019

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

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TRIVANDRUM

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LIST OF EXPERIMENTS

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2. Study of losses in optical fiber.

3. Setting up of fiber optic digital link.

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5. Power vs. Current (P-I) characteristics and measure slope efficiency of Laser Diode.

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OPTICAL COMMUNICATION EXPERIMENTS

1. MEASUREMENT OF NUMERICAL APERTURE OF A FIBRE AFTER PREPARING THE FIBER ENDS.

AIM:

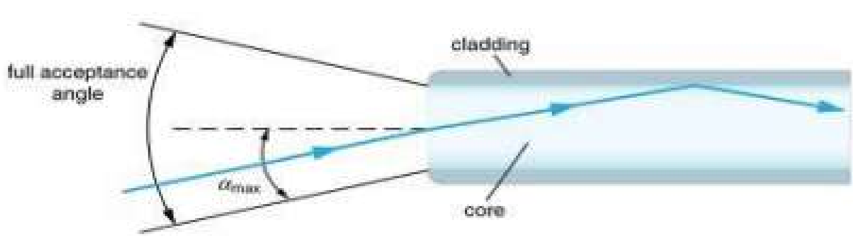
To measure the numerical aperture of the plastic Fiber.

EQUIPMENTS REQUIRED:

OFT, Numerical aperture unit.

THEORY:

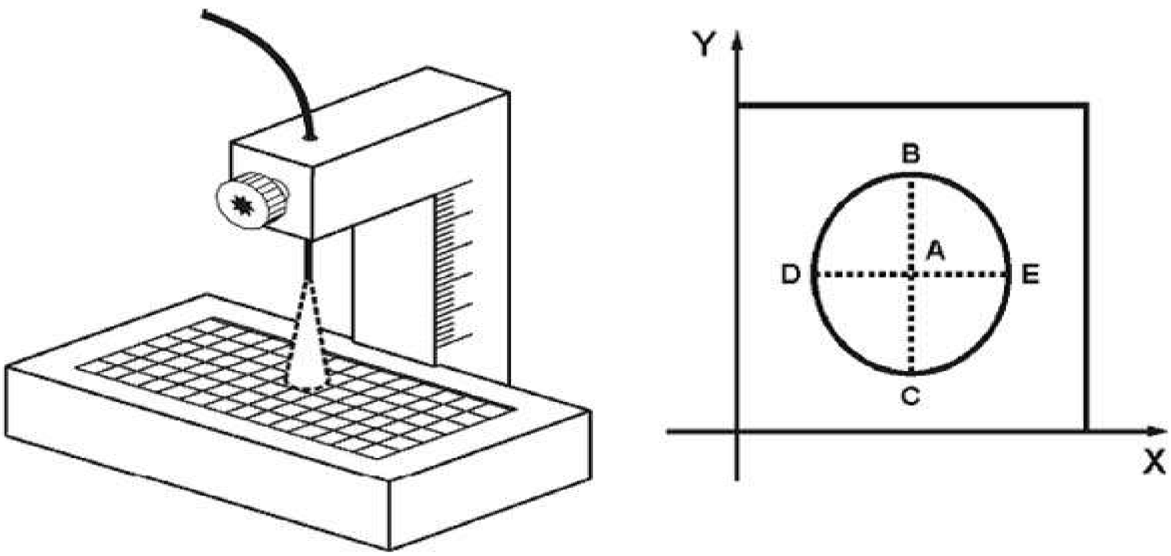
Optical fiber is one of the important elements in an optical fiber link. The performance of the link depends upon the attenuation and dispersion properties of optical fiber, which in turn are function of the input power carried by the cabled fiber. Considered propagation of light in an optical fiber, the condition of total internal reflection at the core-cladding interface is necessary. Therefore, for rays to be transmitted by total internal reflection within the fiber core they must be incident on the fiber core within an acceptance cone defined by the conical half angle (α_{max}). Thus, α_{max} is the maximum angle to the axis at which light may enter the fiber in order to be propagated and is often referred to as the acceptance angle for the fiber.



Light Propagation through optical fiber

EXPERIMENTAL SET UP FOR NUMERICAL APERTURE MEASUREMENT

Numerical aperture measurement unit



A more generally used term, the numerical aperture relates the acceptance angle and refractive index of the three media involved (the core, cladding and air) and is a basic descriptive characteristic of a specific optical fiber. It represents the size or degree of openness of the input acceptance cone. Mathematically it is defined as the sine half angle of the acceptance cone and is a very useful measure of light-collecting ability of a fiber.

Using Snell's law, the maximum angle within which light will be accepted into and guided through optical fiber is Light Propagation through optical fiber

$NA = n_0 \text{ Sin } (\alpha_{max}) = (n1^2 – n2^2)^{1/2}$

Where α_{max} is the half acceptance angle, n0 the refractive index of air and n1 and n2 are the refractive indices of the core and the cladding respectively.

PROCEDURE:

- Connect the end of the fiber to the OFT
- Switch ON the power supply
- Install the measuring stand
- Keep the minimum distance of about 10mm between fiber tip and graph plane.
- Measure and note down the diameter of the circle forward by the light on the graph plane
- Find the value of r
- Increase the intensity of light, we get bright red-light circular patch.
- Now observe the illuminated circular patch of light on the screen.
- Measure exactly the distance d and also the vertical and horizontal Mean radius is calculated using the following formula r = (DE+BC)/4
- Find the numerical aperture of the Fiber using the formula

$NA = \sin\theta_{max} = r / (d^2 + r^2)^{1/2}$

d is the distance between tips of the fiber or height.

<u>TABULATION</u>

DE (mm)	BC (mm)	R=DE+BC/2 (mm)	d (mm)	NA

$$NA = \sin\theta_{max} = r / (d^2 + r^2)^{1/2}$$

$$V = [2\pi a.NA]/\lambda$$

$$\text{Number of modes} = V^2/2$$

The normalized frequency parameter or V number gives the upper limit of the number of te modes that can be transmitted in a multimode optical fiber.

The V number can be calculated by

$V = [2\pi a.NA]/\lambda$

Number of modes = $V^2/2$

RESULT:

Measurement of Numerical aperture of an optical fiber was studied.

2. STUDY OF LOSSES IN OPTICAL FIBERS.

AIM:

The objective of this experiment is to measure propagation loss & bending losses for two different wavelengths in plastic Fiber.

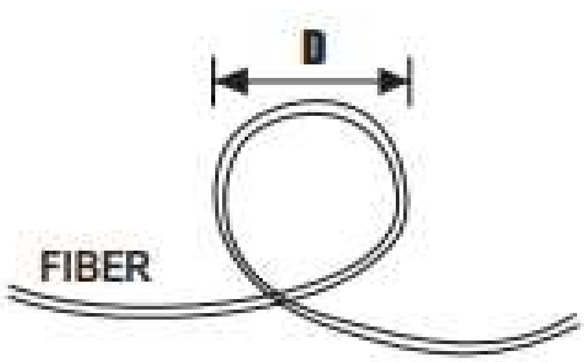
EQUIPMENTS REQUIRED:

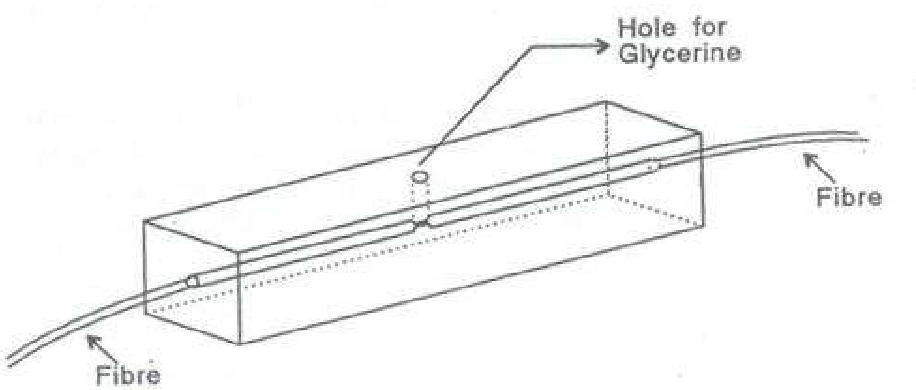
Optical power supply, optical fiber cable, CRO connecting probe power meter, power supply cord

THEORY:

Optical Fibers are available in different variety of materials. These materials are usually selected by taking into account their absorption characteristics for different wavelengths of light. In case of Optical Fiber, since the signal is transmitted in the form of light, which is completely different in nature as that of electrons, one has to consider the interaction of matter the radiation to study the losses in fiber. Losses are introduced in fiber due to various reasons. As light propagates from one end of Fiber to another end, part of it is absorbed in the material exhibiting absorption loss. Also, part of the light is reflected back or in some other directions from the impurity particles present in the material contributing to the loss of the signal at the other end of the Fiber. In general terms it is known as propagation loss. Plastic Fibers have higher loss of the order of 180 dB/Km whenever the condition for angle of incidence of the incident lights is violated the losses is introduced due to refraction of light. This occurs when fiber is subjected to bending. Lower the radius of curvature more is the loss. Other losses are due to the coupling of Fiber at LED & photo detector ends.

FIBER BENDING FOR LOSS MEASUREMENT





Fibre Alignment Using The Fibre Aligning Unit

PROCEDURE:

- Connect the power supply cord to main supply

- Connect the 1m fiber to the source and note the peak value of received signal on the CRO.
- Switch on the instrument fiber optic source (keep the position on 850nm)
- Replace the 1m fiber cable with the 3m cable without disturbing any setting.
- Again note the peak point, this reading will be lesser than previous and indicating that the propagation loss increases with increase in length.

If α is the attenuation/loss in the fiber then, we have

$V1/V3 = \exp\{-\alpha\,(L1-L3)\}$

Where- α= neper/meter,

L1= Fiber length for V1,

L3= Fiber length for V3,

Calculate propagation loss α using above equation.

Measurement of Bending Losses

- Connect the fiber to the power supply and measure the power
- Bend the Fiber in a loop measure the amplitude of the received signal.
- Keep reducing the diameter of bend to about 3 cm & take corresponding out voltage readings. (Do not reduce loop diameter less than 1 cm).
- Plot a graph of the received signal amplitude versus the radius.

Propagation loss

Observation

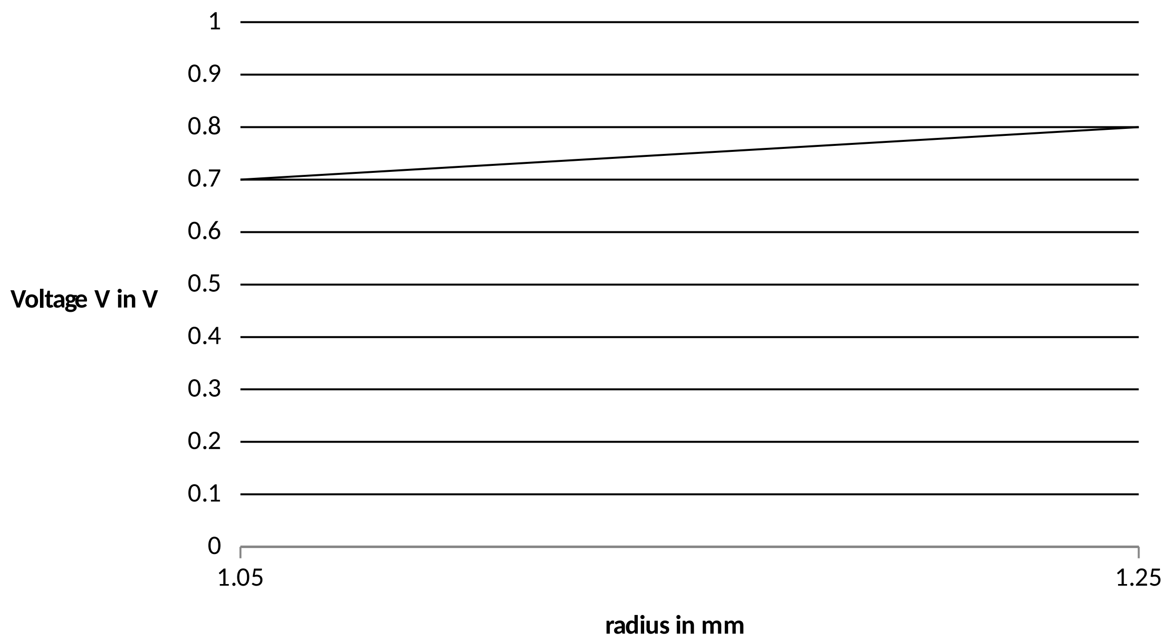
- The measured length of fiber, L1=------meter
- O/P voltage V1 for length of fiber, L1=------Volts
- The measured length of fiber, L3=------meter
- O/P voltage V2 for length of fiber, L3=------Volts

Attenuation loss

Length of the cable	Input signal Amplitude (v)	Output signal Amplitude (v)	Attenuation (dB/m)

Bending loss

Diameter AB[mm]	Diameter CD[mm]	Avg radius[mm]	Voltage[V]



RESULT:

Different losses in optical fiber were studied.

3. SETTING UP OF FIBER OPTIC DIGITAL LINK.

AIM:

To construct a digital communication optical link to transmit digital signals

EQUIPMENTS REQUIRED:

OFT, Function generator, two channel oscilloscope, BNC cable [3]

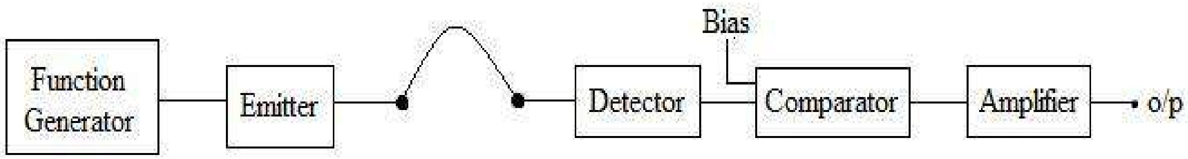
THEORY:

The OFT can be used to set up two fiber optic digital link, at a wavelength of 850nm. LD1, in the optical Tx1 block, is an 850 nm LD. PD1, in the optical Rx1 block, is a PIN detector which gives a current proportional to the optical power falling on the detector. The received signal is amplified and converted to a TTL signal using a comparator. The GAIN control plays a crucial role in this conversion. PD2, in the optical Rx2 block, is another receiver which directly gives out a TTL signal.

PROCEDURE:

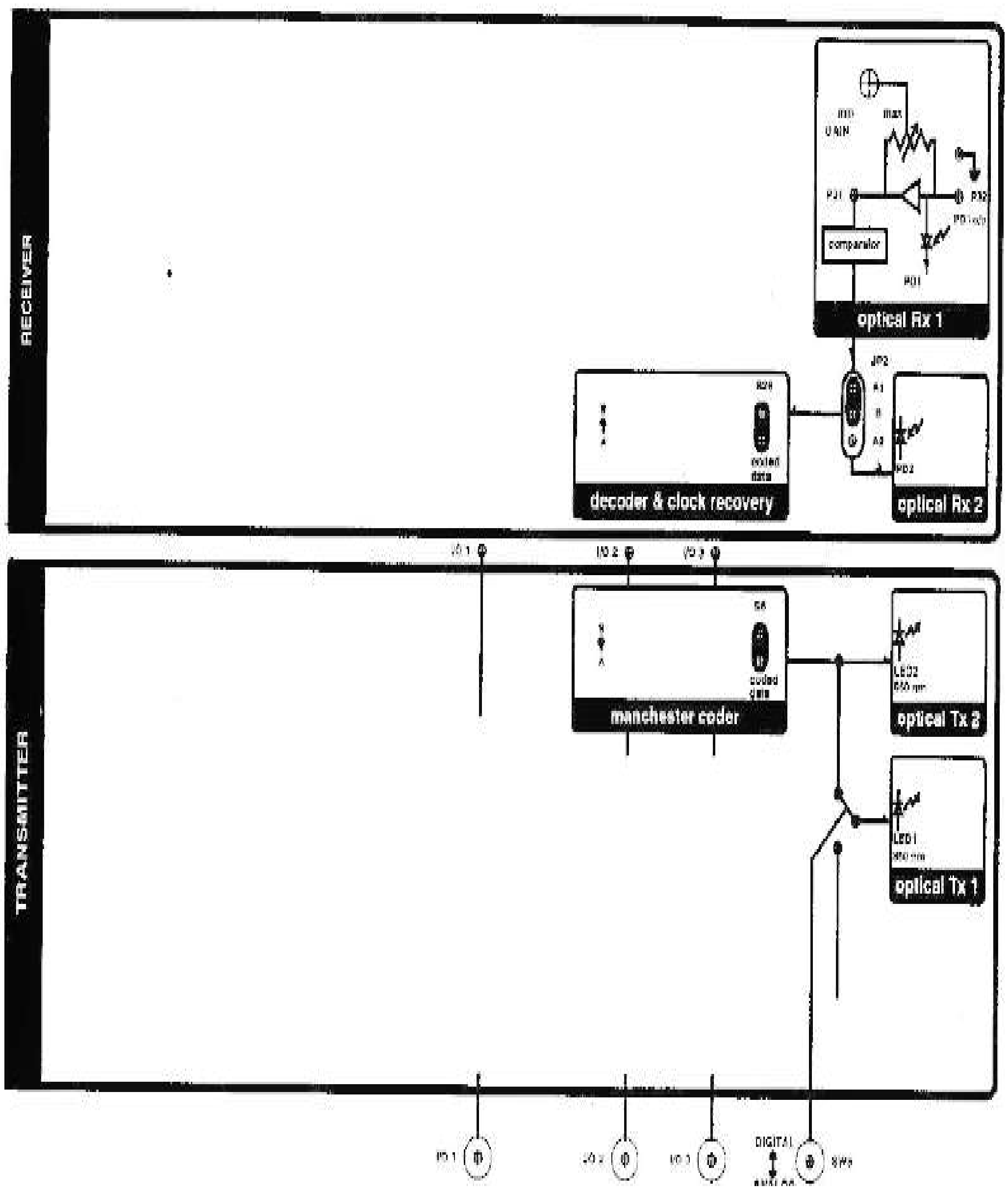
- Connections are made as per the block diagram.
- Set the switch SW8 to the DIGITAL position.
- Connect a 1m optical fiberLD1 and the PIN diode PD1.
- Feed a TTL signal of about 20 KHz from the function generator to post B of S6.
- Use the BNC I/Os for feeding. Observe the received analog signal at the amplifier post P31 on channel 1 of the oscilloscope.
- Observe the received signal at post A of S26 on channel 2 of the oscilloscope while still observing the signal at P31 on channel 1.
- Set the gain such that the signal at P31 is about 2V. Observe the input signal from the function generator on channel 1 and the received TTL signal at post A of S26 on channel 2. Vary the frequency of the input signal and observe the output response

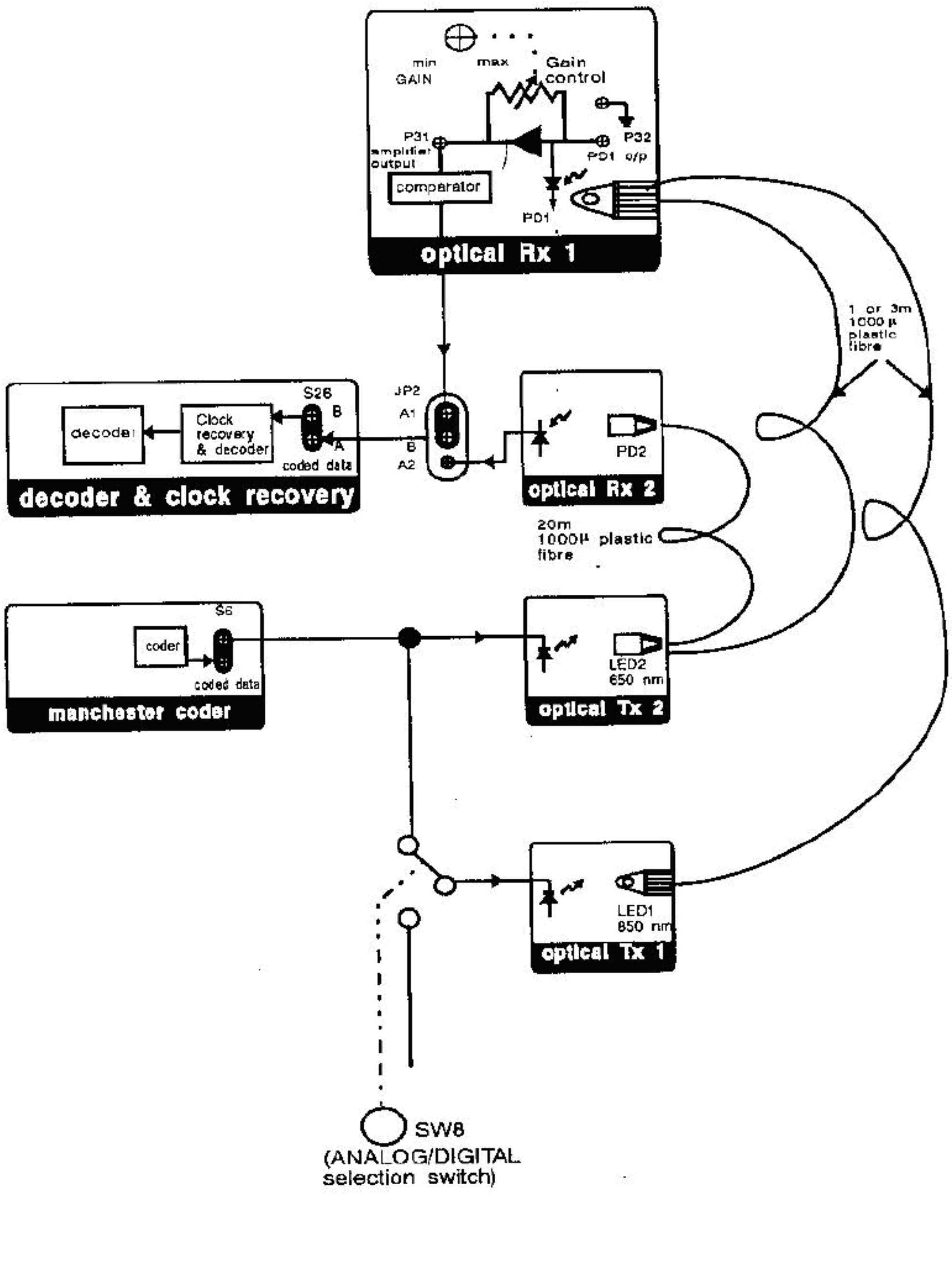
BLOCK DIAGRAM:



SETTING UP A DIGITAL LINK AT 850nm

- Set the switch SW8 to the digital position.
- Connect a 1m optical fiber between LED1 and PIN diode PD1.Remove the shorting plugs of the coded data shorting links, S6 in the Manchester coder block and S26 in the decoder and clock recovery block. Ensure that the shorting plug of jumper JP2 is across the posts B and A1 [for PD1 receiver selection].
- Feed a TTL signal of about 20 KHz from the function generator to post B of S6. Use the BNC I/Os for feeding and observing signals as described in experiment 1.Observe the received analog signal at the amplifier post P31 on channel1of the oscilloscope. Note that the signal at P31 gets cutoff above 3.5v. Increase and decrease the gain and observe the effect.
- Observe the received signal at post A of S26 on channel 2 of channel1 Note that the signal at S26 is the inverted version of the signal at P31. Vary the gain potentiometer setting. Note that even though the received signal at P31 changes with gain, the output at S26 does not .Reduce the gain till the signal at P31 is less than 0.5v.[if the signal does not drop 0.5V even at the lowest gain setting, pull the fiber out slightly at the receiver to reduce level below 0.5 V]. Note that the signal at S26 now becomes all high. This is because the P31 signal is fed to the comparator –cum-inverter to give the signal at S26. The comparator reference voltage is 0.55V, and unless the signal amplitude is greater than 0.55V, the comparator output is high. Verify this.
- Set the gain such that the signal at P31 is about 2V.observe the input signal from the function generator on channel 1 and the received TTL signal at post A of S26 on channel2.vary the frequency of the input signal and observe the output response.
- Repeat steps 4, 5&6 with the 3m fiber.


RECEIVER
optical Rx 1
comparator
decoder & clock recovery
coded data
optical Rx 2
TRANSMITTER
manchester coder
coded data
optical Tx 2
optical Tx 1
DIGITAL



RESULT:

Thus the transmission of digital signals input and output waveforms are measured.

4. PREPARATION OF SPLICE JOINT AND MEASUREMENT OF SPLICE LOSS.

AIM:

Preparation of splice joint and measurement of splice loss

EQUIPMENTS REQUIRED:

FSM 50S arc fusion splicer, Variable voltage power supply, Simplex assembly 228087-1,Needle-nose pliers, Retention clips 228046-1, Single-edge razor blade or sharp knife, Splice 228051-1, Miscellaneous electrical test leads, Infrared LED, Solder less breadboard, Simplex receptacle 228042-1, 18-gauge wire stripper, 390Ω resistor

THEORY:

Fiber optics technology is not “perfect” because some light is lost as it travels down the optical core. Light loss inside the fiber, or attenuation, is called “intrinsic” loss. This intrinsic loss can be categorized as either scattering or absorption. Fiber optics system cannot always be installed with a single uninterrupted length of optical fiber. Often, two or more fiber length must be joined in order to obtain a necessary length, or route through buildings and enclosures. Losses from these connections are called “extrinsic loss” because they occur outside the optical fiber core and cladding boundary. The two most common extrinsic losses due to joining or connecting optical fiber occur at:

Splices- Permanent connections of two optical fiber length that may be thermally fused or mechanically applied.

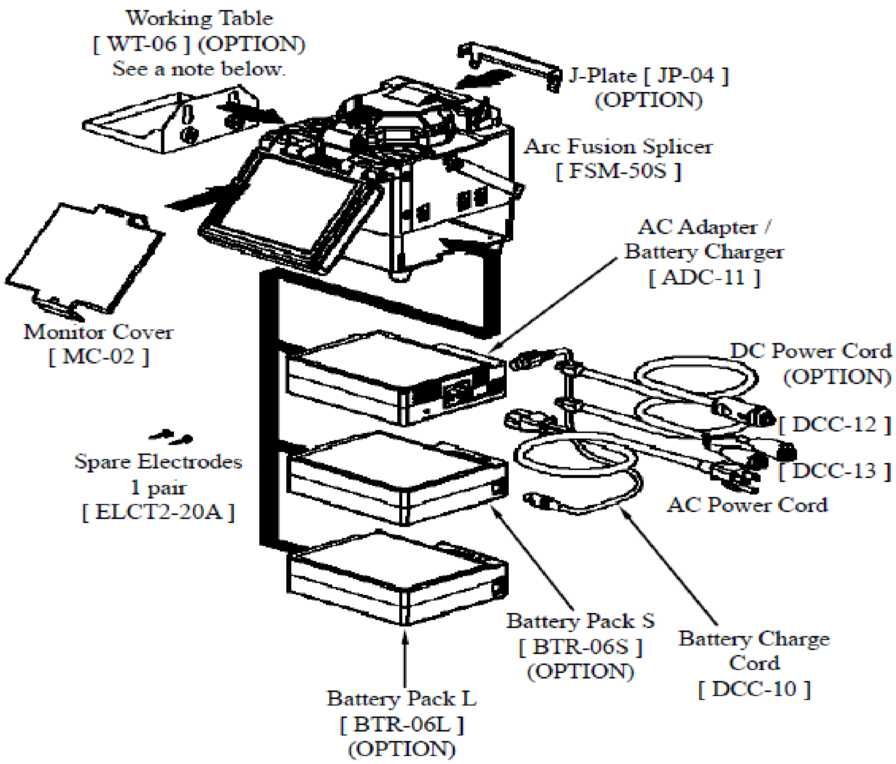
Connectors-Junctions that allow an optical fiber to be readily attached or detached from a light source, detector or another fiber.

1. Inserting Power Supply into Splicer

   For AC operation or DC operation with external battery, use AC adapter for battery operation use detachable battery. The power unit dock, located on splicer body can accommodate both power supplies.

FSM – 50S arc fusion splicer

COMPONENTS OF SPLICER



2. Turning splicer ON

   Press ON button and press it until LED on the keyboard turns ON. The READY screen is displayed after all the motors reset to their initial position. The power source type is then identified. If the battery is used the remaining battery capacity is displayed.

3. Setting sleeve centering device

   Open the tube heater lid, and slide gauge indicator to match the length of the protection sleeve used.

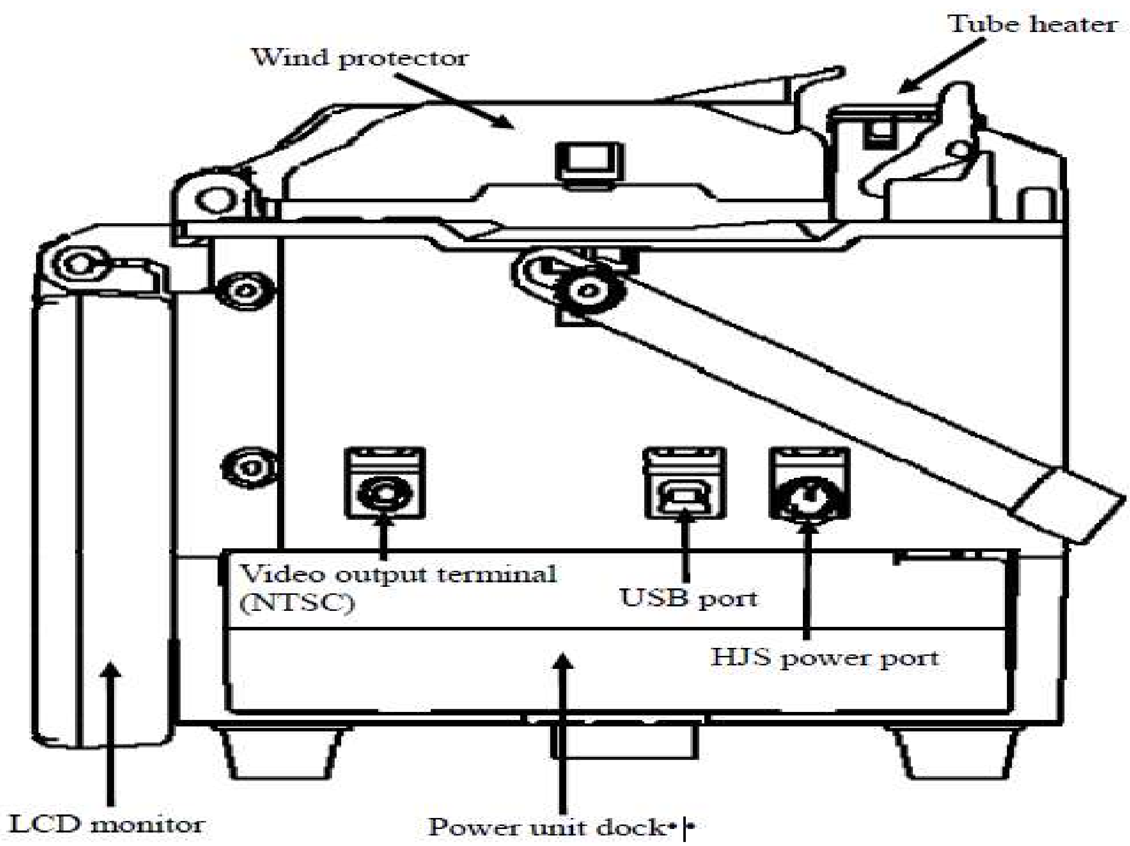
4. Cleaning optical fiber

   Clean optical fiber with alcohol-impregnated gauze or lint free tissue approximately 100m from the tip. Dust particulars from the fiber coating surface can enter inside the protection sleeve and might result in future fiber break or attenuation increase.

5. Placing protection sleeve over the fiber. Protection sleeve over the fiber
6. Stripping and cleaning fiber

   Strip the outer coating 30-40mmfrom its tip with a stripping tool. Clean optical fiber with alcohol-impregnated gauze or lint free tissue thoroughly. Use fresh gauze or wipe only. Do not use gauze or wipe twice.

7. Fiber Cleaving
   - To unlock the cutting lever press it gently and slide the stopper
   - Push the slide button until it locks
   - Set the stripped optical fiber on the cleaver
   - Press down the cutting lever
   - Release the pressure on the cutting lever
   - The scrap collector rollers drive the fiber scrap container box automatically when the cutting lever is raised.


Tube heater
Wind protector
Video output terminal
(NTSC)
USB port
HJS power port
LCD monitor
Power unit dock

When the cleaver is to be put up for the day, press the cutting lever down until stopper can slide into place to lock the anvil lever

8. Place Loading fiber into splicer
   - Open wind protector and sheath clamps
   - Place prepared fiber onto v-groove so that the fiber tip is located between the v-groove edge and tip of the electrode
   - Hold the fiber with fingers and close sheath clamp so that the fiber does not move. If the fiber is not placed properly reload the fiber
   - Load another fiber in the same manner as above.
   - Close wing protector

PROCEDURE:

1. Fiber loaded in the splicer move forward towards each other. The fiber forwarding motion stops at a certain position shortly after cleaning arc is performed. Next the cleave angle and the end face quality are checked. If the measured cleave angle is greater than its set threshold or fiber chipping is detected, the buzzer will sound and an error message warns the operator. The splicing procedure pauses. If no error message is displayed, the below stated end face conditions are used for visual inspection. If observed, remove the fiber from the splicer and repeat fiber preparation. These visual defects may cause a faulty splice.
2. After fiber inspection, the fibers are aligned core to core or cladding to cladding. Cladding axis offset and core axis offset measurement can be displayed.
3. After completion of fiber alignment, arc discharge is performed to splice the fibers.
4. Estimated splice los is displayed upon of completion of splicing. Splice loss is affected by certain factors. These factors are taken into account to calculate, or estimate, splice loss. The calculation is based on certain dimensional parameters, such as MFD.

   If either the cleave angle measured or the estimated splice loss exceeds its set threshold, an error message is displayed. If the spliced fiber is detected as abnormal, such as fat, thin, or bubble, an error message is displayed. If no error message is displayed but the splice looks poor by visual inspection through the monitor, it is strongly recommended to repeat the splice from the beginning.

RESULT:

Splice joint is prepared and measured the splice loss.

5. POWER vs. CURRENT (P-I) CHARACTERISTICS AND MEASURE SLOP EFFICIENCY OF LASER DIODE.

AIM:

To study and plot the I- P Characteristics and measure slop efficiency for 1310nm Laser source for the CW

EQUIPMENTS REQUIRED:

OFT power supply (OFT power supply can be used for LD module), A digital multi-meter Benchmark LD unit, Benchmark LD driver module with its accessories, Benchmark Fiber Optic Power meter with ST adaptor, Mounting Posts

THEORY:

The semiconductor junction laser is also called an injection laser because its pumping method is electron-hole injection in a p-n junction. The semiconductor that has been extensively used for junction is the Gallium Arsenide. The features of semiconductor lasers are

- Extreme mono chromaticity
- High directionality

Three basic transition process related to operation of Lasers are

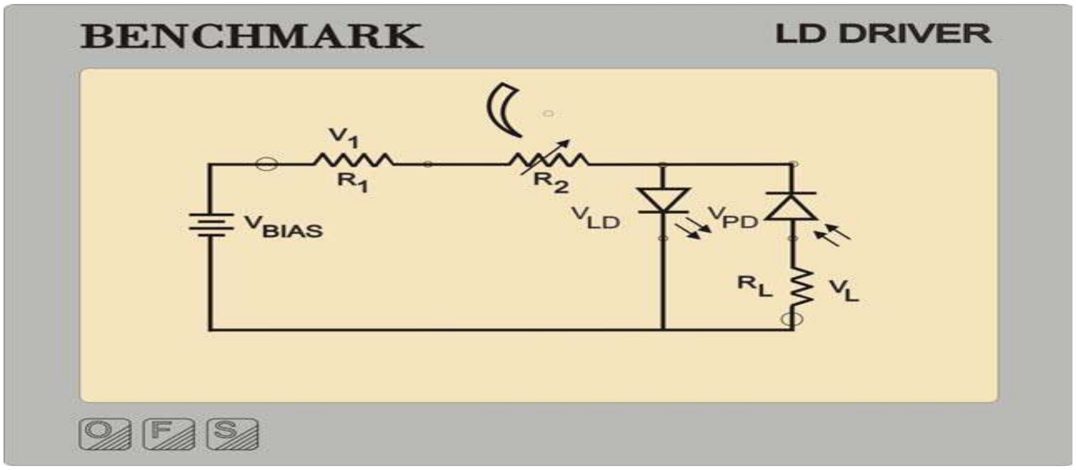
- Absorption
- Spontaneous emission
- Stimulated emission

PROCEDURE:

- Setup the LD module as said in the system setup procedure in the previous chapter and turn it off as recommended.
- Do not disturb this mechanical setup until the experiment is over. Keep the pot at the minimum position. Turn ON the power to the module.
- Measure the voltage V_1 across the resistor R1 and calculate the current through the LD I_{LD} which is given as $I_{LD} = V_1/68$

  Where 68 is the value of resistor R1

EXPERIMENTAL SETUP



OBSERVATION

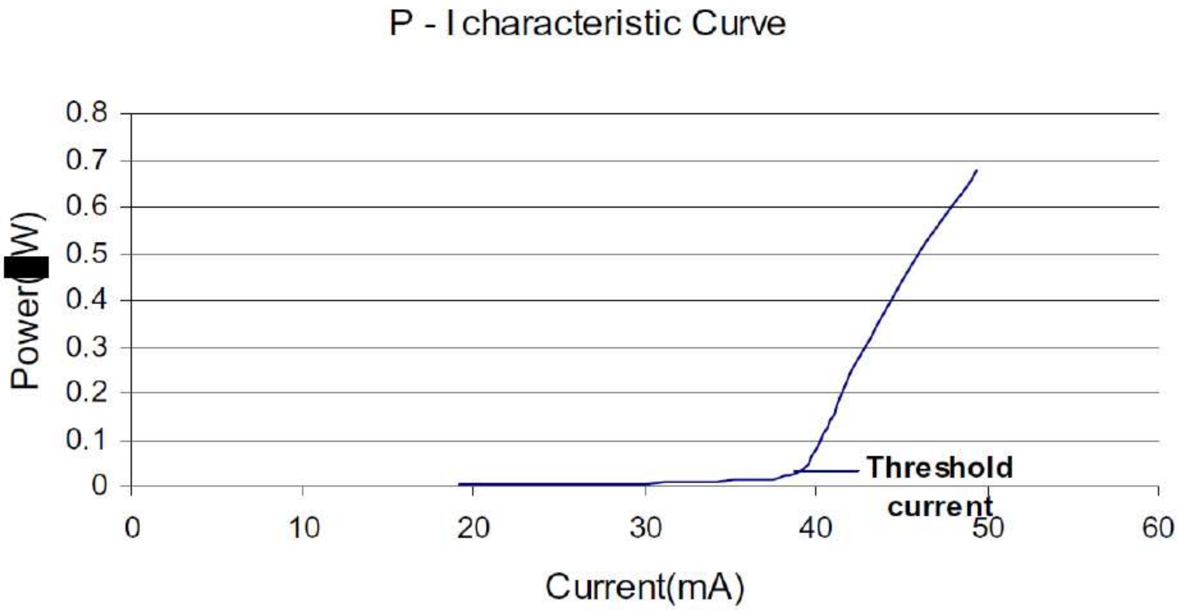
R1=68Ω

- Record the current in mA and the corresponding power in Watts.
- Repeat the procedure for current readings up to the 45mA.
- Measures slop efficiency for 1550nm.

- Now without changing any voltage or the multi-turn pot position, measure the optical power output P of the LD.
- Calculate the power in mW which is given as
  $P_0 = 10^{P/10}$

S.No.	V_1 Volts	I_{LD} mA	V_{LD} Volts	P dBm	P_0 mW

- Increase the current through LD by turning the multi-turn pot clockwise direction slightly towards the maximum till you get a convenient reading V_1 and repeat the steps 2 to 5


P - I characteristic Curve
Power([redacted]W)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Threshold current
0
10
20
30
40
50
60
Current(mA)

RESULT:

The P-I characteristic and slop efficiency for 1550nm Laser source for the CW was studied**.**

6. VOLTAGE vs. CURRENT (V-I) CHARACTERISTICS OF LASER DIODE.

AIM:

To study and plot the V-I characteristics for 1550nm Laser source for the CW

EQUIPMENTS REQUIRED:

OFT power supply (OFT power supply can be used for LD module), A digital multi-meter Benchmark LD unit, Benchmark LD driver module with its accessories, Benchmark Fiber Optic Power meter with ST adaptor, Mounting Posts

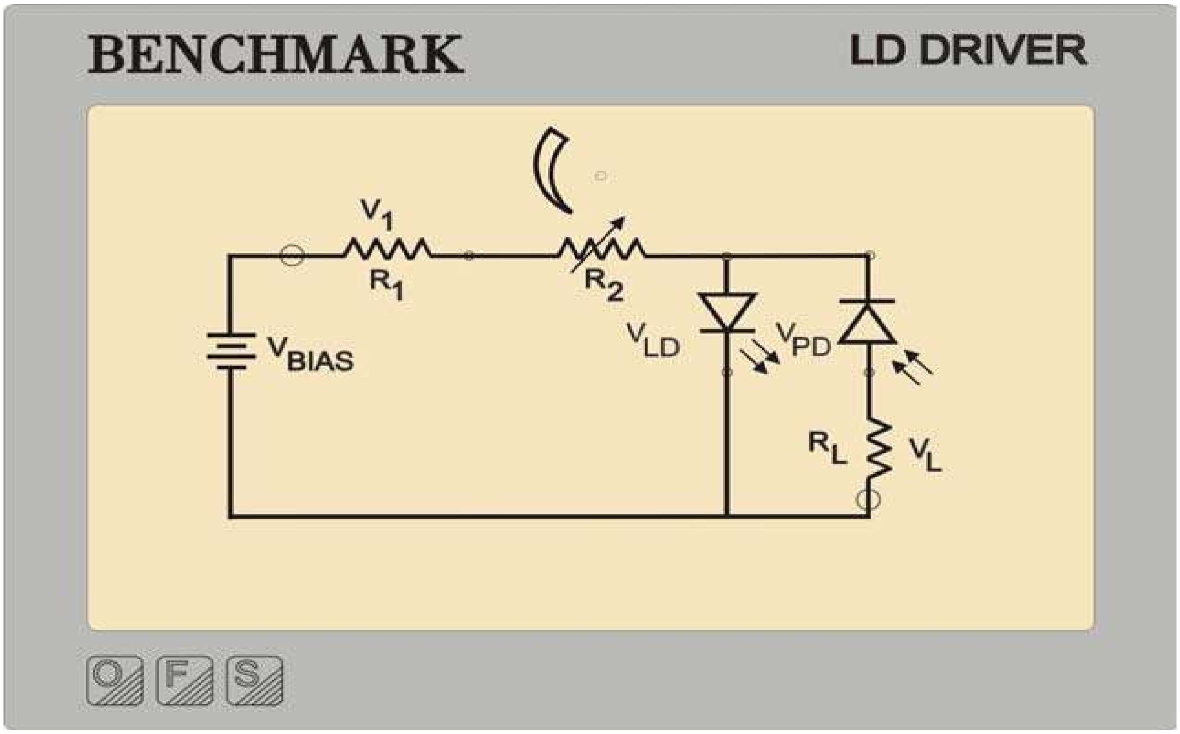
THEORY:

A laser diode is a laser where the active medium is a semiconductor similar to that found in a light-emitting diode. A laser diode, like many other semiconductor devices, is formed by doping a very thin layer on the surface of a crystal wafer. The crystal is doped to produce an n-type region and a p-type region, one above the other, resulting in a p-n junction, or diode.

PROCEDURE:

V-I characteristics for 1550nm Laser source

- Setup the LD module as said in the system setup procedure in the previous chapter and turn it off as recommended.



- • Do not disturb this mechanical setup until the experiment is over. Keep the pot at the minimum position. Turn ON the power to the module.
- Measure the voltage V_1 across the resistor R1 and calculate the current through the LD I_{LD} which is given as $I_{LD} = V_1/68$

  Where 68 is the value of resistor R1
- Plot voltage verses current graph

EXPERIMENTAL SETUP

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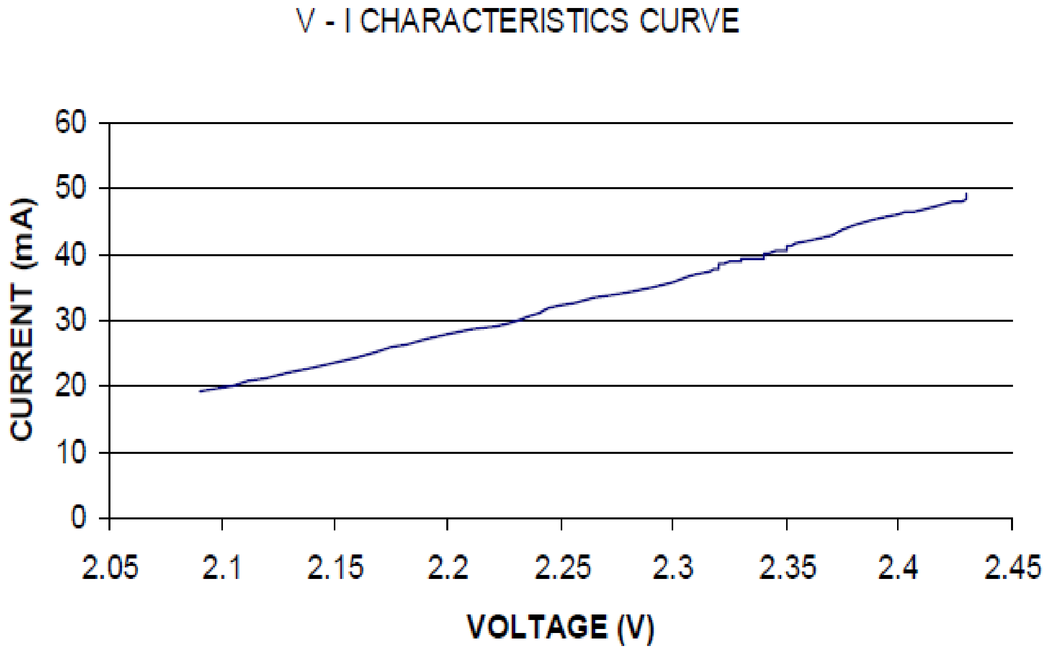
<u>OBSERVATION</u>

SL. NO	CURRENT THROUGH LASER (mA)	Voltage Across LASER (v)

R1= 68Ω FOR 1550nm

RESULT:



The V-I characteristics for 1550nm Laser source.

7. POWER vs. CURRENT (P-I) CHARACTERISTICS AND MEASURE SLOPE EFFICIENCY OF LED.

AIM:

To determine the P-I characteristics and measure slope efficiency of fiber optic LED

EQUIPMENTS REQUIRED:

OFT Power supply, a digital multi-meter, LED Module, Benchmark Fiber Optic Power Meter, Bare fiber adaptor – Plastic, 1.25m Plastic fiber

THEORY:

In optical fiber communication system, electrical signal is first converted into optical signal with the help of E / O conversion device as LED. After this optical signal is transmitted through optical fiber, it is retrieved in its original electrical form with the help of O / E conversion device as photo detector.

The most significant features of LEDs, which are used for optical communication, include high modulation rate capability, high radiance, high reliability and emission wavelengths restricted to the near infrared spectral regions of low attenuation in fibers.

PROCEDURE:

- Connect the OFT power supply properly to the module using the DIN-DIN cable provided with the power supply. Turn the multi-turn pot to its minimum position and switch ON the module.
- Measure the voltage V_1 across the resistor R_1 (180ohms) and calculate the current through the LED I_f which is given as

$$I_f = V_1/180$$

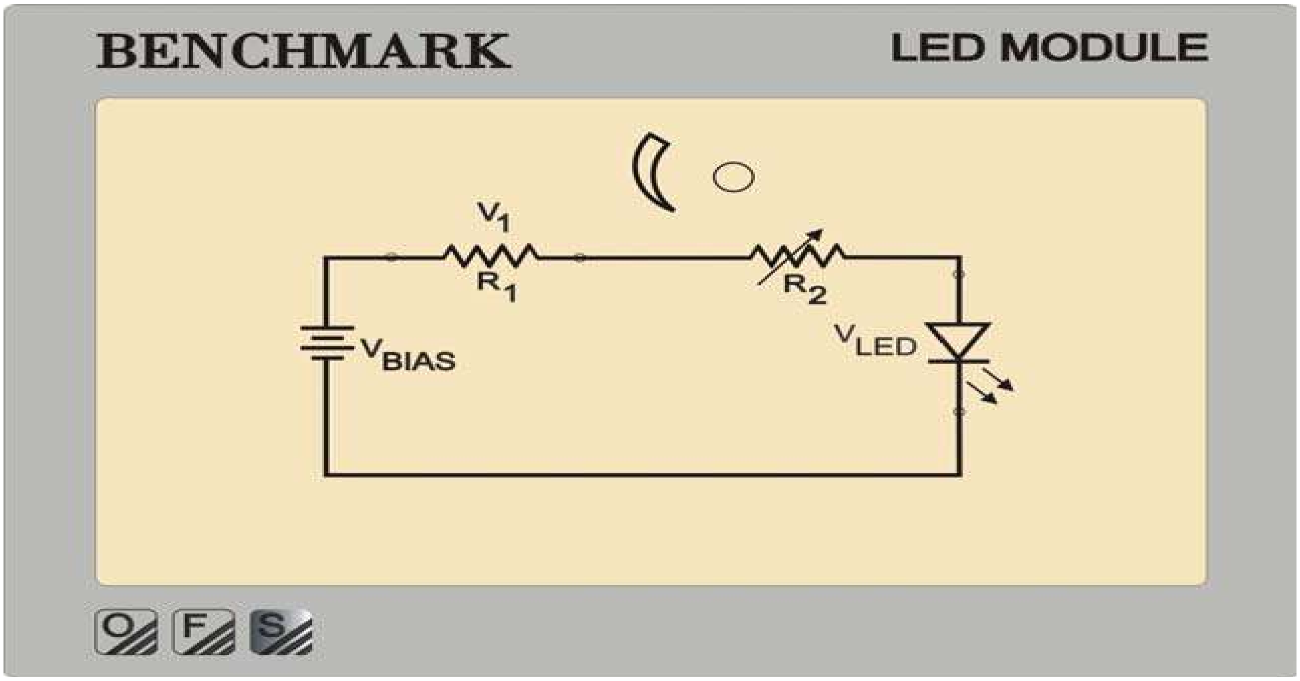
- Now measure the voltage V_{LED} across the LED and note down.
- Remove the dummy adaptor cap from the power meter PD exposing the large area photo-detector. Mount the bare fiber adaptor – plastic over the PD. Carefully hold the LED source very close to the photo-detector window perpendicular to it to couple all the optical power from the LED to the power meter. Now without changing any voltage or the potentiometer, measure the optical power output P of the LED.
- Plot the graph of forward current v/s output optical power of the LED.
- Calculate the power in mW and note it down which is given as

$$P_0 = 10^{P/10}$$

- Calculate the E-O conversion efficiency ‘η' of the LED from the plotted graph ‘I_f’ Vs P_0 which is given as

$$\eta = P_0 / I_f$$

- Measure slope efficiency of fiber optic LED



TABULATION

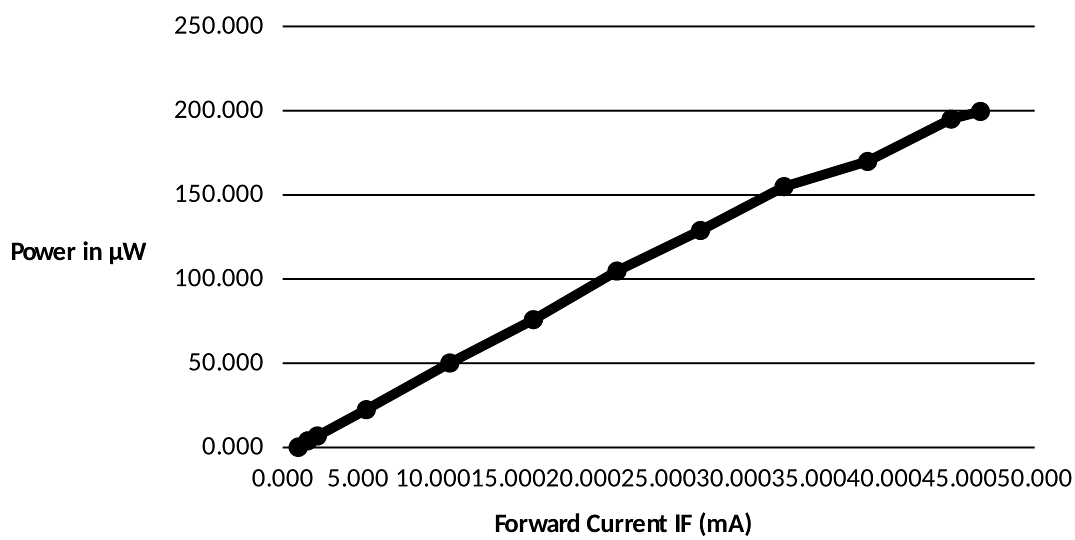
LED CHARECTERISTICS

850nm

S.No.	V_1 V	I_f mA	V_{LED} V	P dBm	P_0 mW

R1 = 180Ω

Sample graph



RESULT:

The P-I characteristics and slop efficiency of LED were determined.

8. VOLTAGE vs. CURRENT (V-I) CHARACTERISTICS OF LED.

AIM

To study and plot the V-I characteristics LED source for the CW

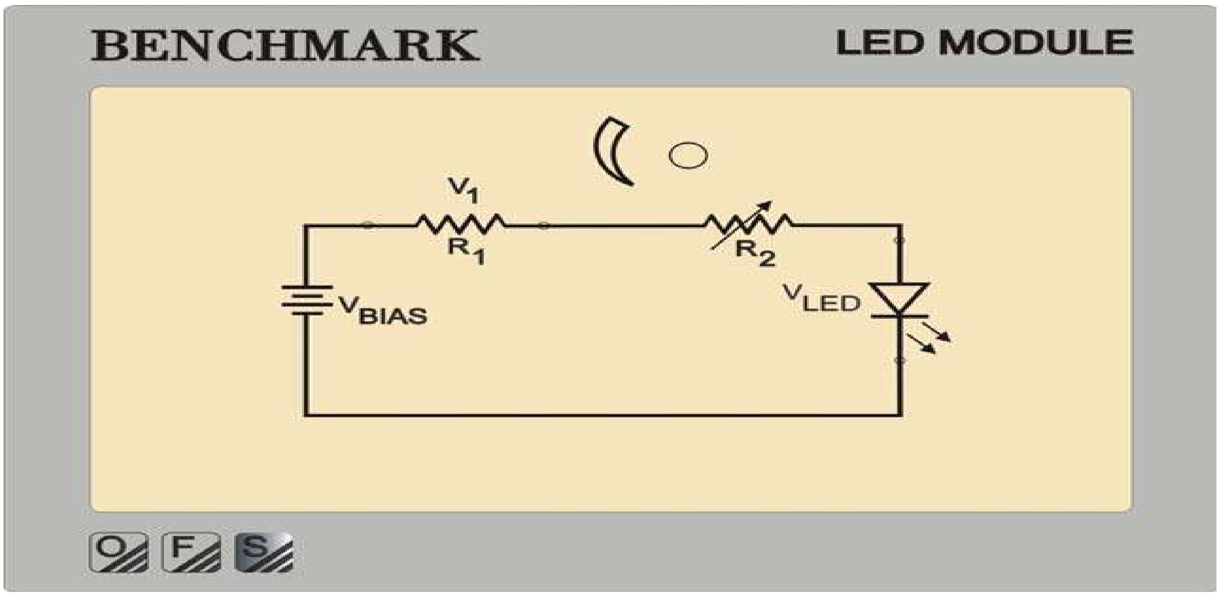
EQUIPMENTS REQUIRED:

OFT Power supply, A digital multi-meter, LED Module, Benchmark Fiber Optic Power Meter, Bare fiber adaptor – Plastic, 1.25m Plastic fiber

THEORY:

A Light Emitting Diode (LED) is a semiconductor diode that emits light when an electric current is applied in forward direction of the device as in simple LED circuit. The effect is a form of electroluminescence where incoherent and narrow-spectrum light is emitted from the p-n junction.

To be useful in fiber transmission applications and LED must have a high radiance output, a fast emission response time and high quantum efficiency. To achieve a high radiance and high quantum efficiency, the LED structure must provide a means of confining the charge carriers and the stimulated optical emission to the active region of the pn junction where radiative recombination takes place.



PROCEDURE:

- Connect the OFT power supply properly to the module using the DIN-DIN cable provided with the power supply. Turn the multi-turn pot to its minimum position and switch ON the module.
- Measure the voltage V_1 across the resistor R_1 (180ohms) and calculate the current through the LED I_f which is given as

$$I_f = V_1/180$$

- Now measure the voltage V_{LED} across the LED and note down.
- Repeat the procedure for current readings up to the mA.
- Plot the graph for Current (mA) vs Voltage (v).

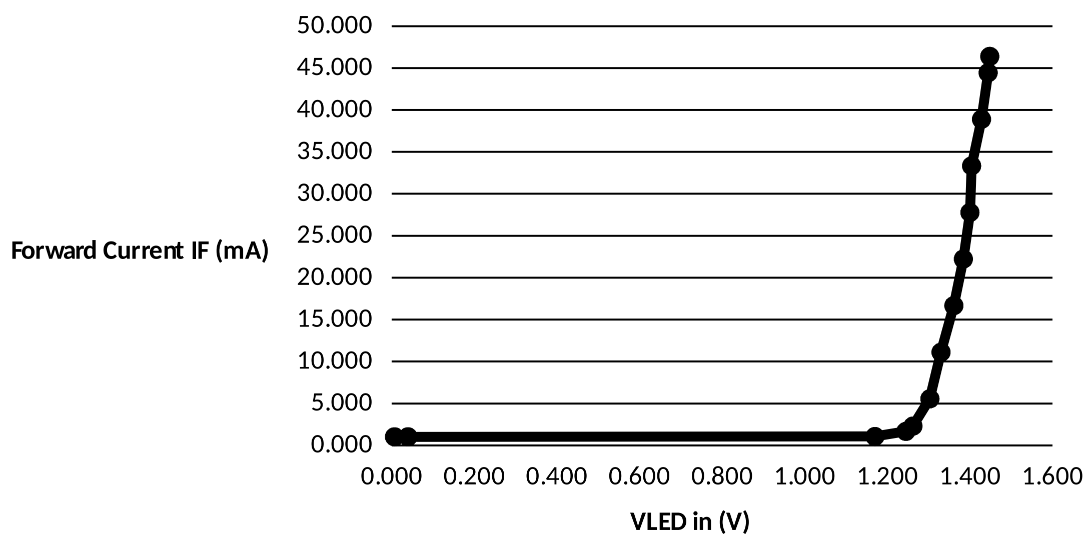
EXPERIMENTAL SETUP

OBSERVATION

Voltage V1 (V)	**Voltage VLED (V)**	**Forward Current I_f (mA)**

850nm
R1 =180Ω

Sample graph



RESULT:

The V-I characteristics of LED source for the CW was studied.

9. CHARACTERISTICS OF PHOTODIODE AND MEASURE THE RESPONSIVITY.

AIM:

To plot the characteristics of photo diode and determine the resposivity.

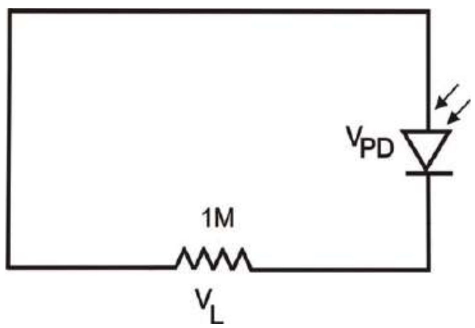
EQUIPMENTS REQUIRED:

OFT power supply ,A digital multi-meter ,PD Module ,Benchmark Fiber Optic Power Source ,Benchmark Fiber Optic Power Meter ,1m Patch cord (PSTO-PC-1) ,1 M ,10K resistors

THEORY:

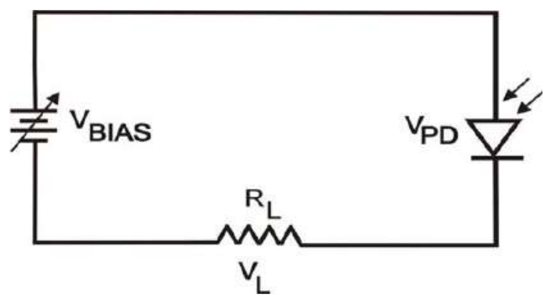
A silicon photodiode is a solid state light detector that consists of a shallow diffused P-N junction with connections provided to the outside world. When the top surface is illuminated, photons of light penetrate into the silicon to a depth determined by the photon energy and are absorbed by the silicon 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.

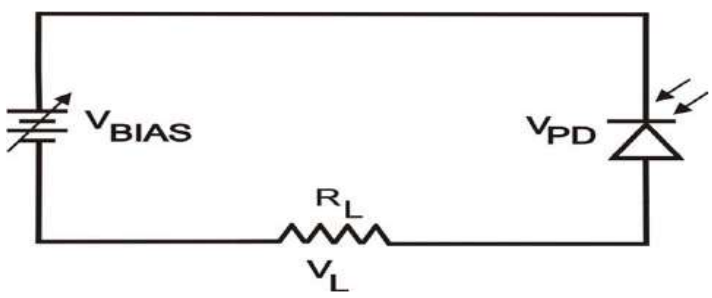
If an external connection is made to both sides of the junction a photo induced current will flow as long as light falls upon the photodiode. In addition to the photocurrent, a voltage is produced across the diode. In effect, the photodiode functions exactly like a solar cell by generating a current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



Zero bias

forward bias





Reverse bias

PROCEDURE:

- Connect the OFT power supply to the module using the DIN-DIN cable provided with the power supply. Set the bias switch to the zero bias configuration (Bias switch moved to the top most position).

Turn the bias voltage varying pot in the PD module to its minimum position and switch ON the module. The zero bias LED lights up.

- The module at the zero bias photodiode is given no bias voltage. The current induced by the photo-detector due to the incident optical power on to it, flows through the load resistor.
- Put 1Mohm resistor across V_L.
- Connect the ST connector end of the patch cord supplied with the module to the power source.
- Set the Power source in CW mode and to give maximum output power (refer Benchmark power source manual on how to adjust the power). Connect 1m patch cord between source and meter (use bare fiber adaptor - plastic at the power meter end) and measure this optical power P and adjust the power in source such that it reads -18dBm approx. Note down this power.
- Slightly unscrew the black colored cap of the PD to loosen it, without removing it from the connector assembly. Remove the patch cord from the power meter and gently push the fiber into the black cap until it is held in place. Now tighten the black cap by screwing it back. The fiber will now be held firmly in place. Now measure the voltage across V_L

$\mathbf{I_z = V_L/1x10^6}$

Forward bias

- Connect the OFT power supply to the module using the DIN-DIN cable provided with the power supply. Set the bias switch to the forward bias configuration (Bias switch moved to the middle position). Turn the bias voltage varying pot in the PD module to its minimum position and switch ON the module. The forward bias LED lights up.
- Put 10K resistor across V_L.
- Adjust the potentiometer and fix the bias voltage at 10V
- Connect the ST connector end of the patch cord supplied with the module to the power source.

- Set the Power source in CW mode and to give maximum output power (refer Benchmark power source manual on how to adjust the power). Connect 1m patch cord between source and meter (use bare fiber adaptor - plastic at the power meter end) and measure this optical power P and adjust the power in source such that it reads -18dBm approx. Note down this power.

$$I_f = V_L/10x10^3$$

- Plot the graph P vs. I_f.

Reverse bias

- Connect the OFT power supply to the module using the DIN-DIN cable provided with the power supply. Set the bias switch to the reverse bias configuration (Bias switch moved to the bottom most position). Turn the bias voltage varying pot in the PD module to its minimum position and switch ON the module. The reverse bias LED lights up.
- Put 10K resistor across V_L.
- Adjust the potentiometer and fix the bias voltage at 10V. Connect the ST connector end of the patch cord supplied with the module to the power source.
- Calculate the power in microwatt

$$I_R = V_L/10x10^3$$

Power [μW] = 1mW * $10^{Power \in dB/10}$

- Calculate the responsivity from :

R_λ = VL/(RL*PS) A/W where PS is the power in Watts.

$$\eta = R_\lambda \, h \, \nu / e \times 100\%$$

Where h is the Planck's constant = 6.64 x 10^{-34} JS,ν is the frequency of the incident photons

$= C/\lambda = 3 \times 10^{8} / 850 \times 10^{-9}$ Hz

e is the electric charge = 1.6×10^{-19} Coulombs

OBSERVATION

Zero bias

$R_L = 1\ M\Omega$

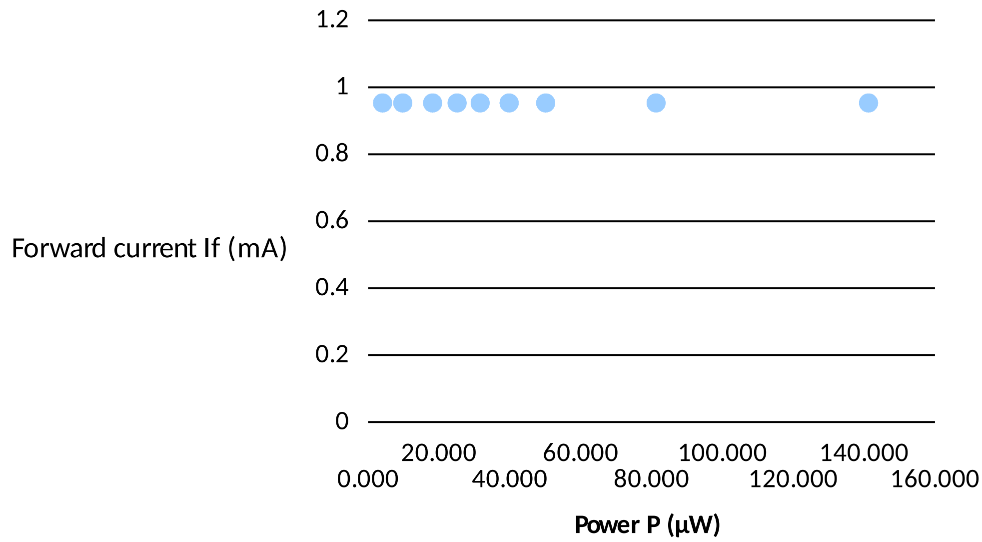
$Iz = VL/1000000$

Forward bias

P-I characteristics

$V_{bias} = 10$ V, $R = 10\ k\Omega$, $I_f = VL/10000$

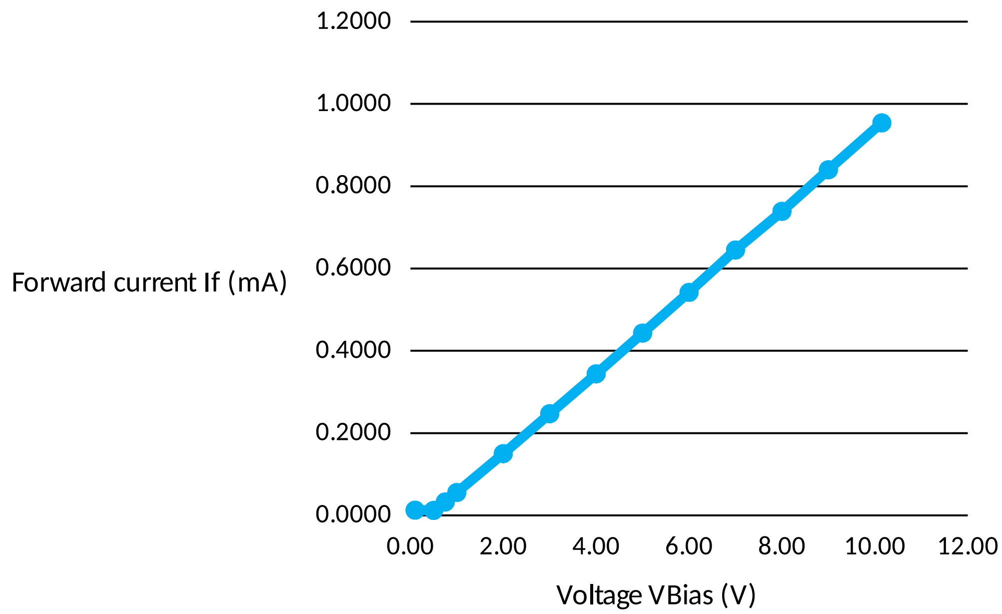
S.No.	Power P dBm	Power P_0 μW	V_L Volts	I_z μA



V –I characteristics

V_{bias} in V	V_L in V	I_f in mA

R = 10 kΩ, Power = -15 dBm, I_f = VL/10000

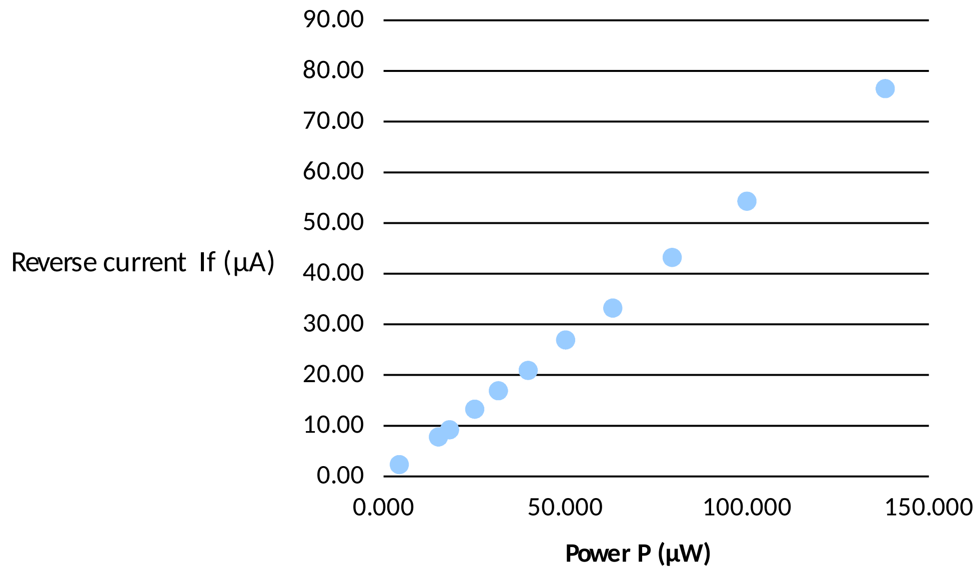


Reverse bias

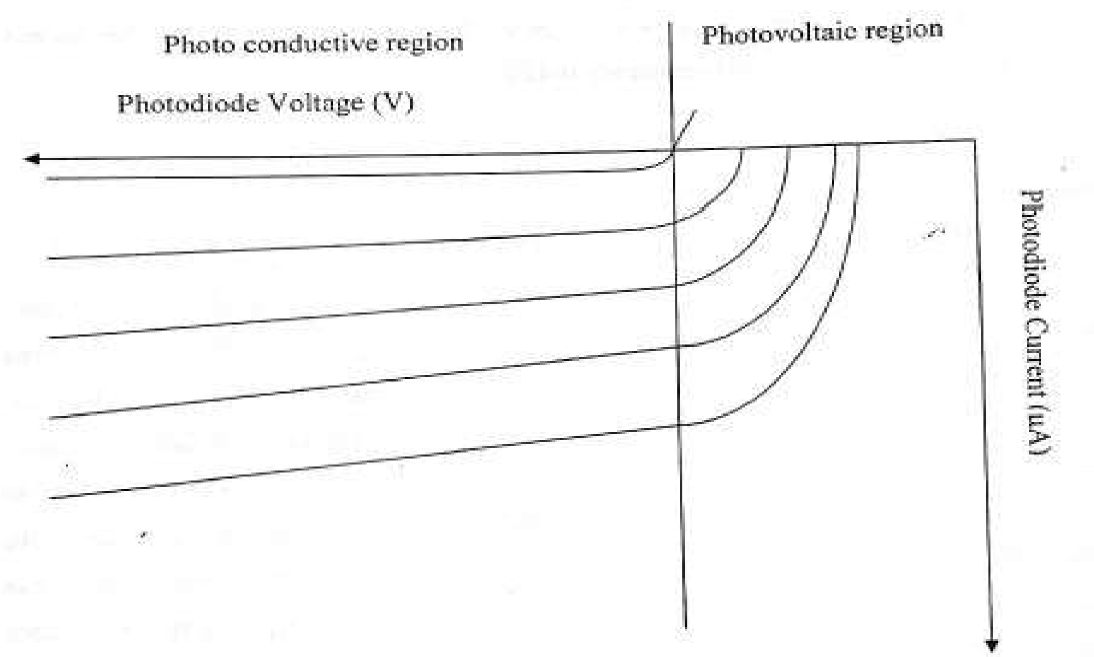
<u>P-I characteristics</u>

S.No.	Power P dBm	Power P µW	V_L V	I_R mA

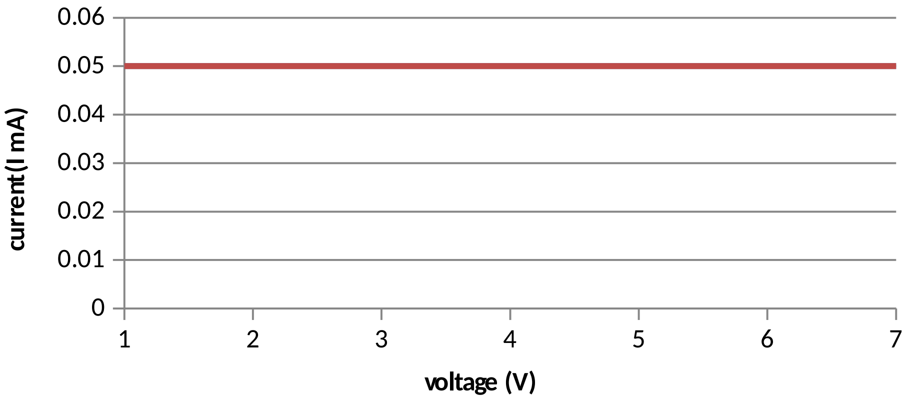
V bias = 10.15, R = 10 kΩ V, I_R = VL/10000



V-I characteristics



Voltage(V)	V_{PD}(V)	I (mA)



Responsivity

RL = 10kΩ, I_R = VL /10000

R_λ $=V_L/ (RL * Ps)$

V_{BIAS} (V)	$V_{L (V)}$	I_R (mA)	Power (dBm)	Power (W)	R_L (Ω)	R_λ (A/W)

Average Responsivity =…………….

η = [R_λ * h]*[v /e]* 100%

Efficiency = …………………………

RESULT:

Studied the Photodiode characteristics and measured the responsivity.

10. CHARACTERISTICS OF AVALANCHE PHOTO DIODE (APD) AND MEASURE THE RESPONSIVITY.

AIM:

To measure a number of important characteristics of an Avalanche Photo Diode (APD) and Responsively (R_λ) of an APD.

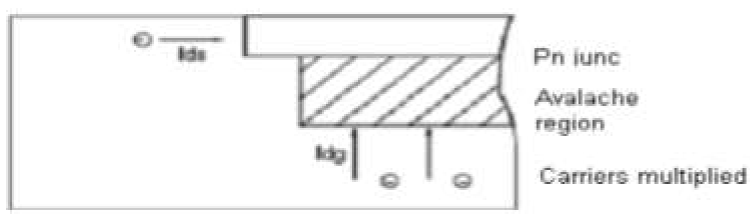
EQUIPMENT REQUIRED:

APD power supply, A digital multi-meter, APD module, ST-ST multimode patch cord (ST-PC-1) , Benchmark Fiber Optic Power Source ,Benchmark Fiber Optic Power Meter

THEORY

1. Dark Current VS. Reverse Voltage

The APD dark current is categorized into surface leakage current Ids flowing through the interface between the PN junction and InGa oxide layer and internal current Idg generated inside the InGa substrate.



APD dark current

The surface leak current is not multiplied because it does not flow in the avalanche region, but the internally generated current flows in the avalanche region so it is multiplied. The total dark current ID produced from an APD becomes as follows.

ID = Ids + M* Idg.. (1-4)

Where M is the multiplication ratio or gain Figure 1-3 graphically shows how the dark current changes with the reverse voltage. It is clear that Idg increases as the reverse voltage rises.

2. Gain vs. Reverse Voltage

The APD multiplication ratio (gain) depends on the electric field applied across the avalanche layer. Normally, the higher the reverse voltage, the higher the gain will be. However, if the reverse voltage is increased further, a voltage drop occurs due to the current flowing through the device series resistance and load resistance, causing the voltage applied to the avalanche layer to decrease. This means that the APD has a maximum gain whose value is dependent on the photocurrent. When the APD is operated near this maximum gain, the voltage drop tends to increase due to the series resistance component, resulting in an unwanted phenomenon in which the output photocurrent is not proportional to the amount of incident light. The APD gain also has temperature-dependent characteristics. The gain at a certain reverse voltage becomes small as the temperature rises. This is because the crystal lattice vibrates more heavily with an increasing temperature, and the accelerated carriers are apt to collide with the lattice before reaching an energy level sufficient to trigger ionization. To obtain a constant output, it is necessary to adjust the reverse voltage according to the changes in temperature or to keep the APD temperature constant. The temperature coefficient of gain is commonly expressed in V/°C or %/°C. When an APD is operated at a gain of 100, the temperature coefficient of the Reverse voltage will be almost equal to that of the breakdown voltage.

3. Spectral Response

Spectral response characteristics of APDs are almost the same as those of normal photodiodes if a reverse voltage is not applied. When a reverse voltage is applied, the spectral response curve will change slightly. This is because the multiplication efficiency of carriers injected into the avalanche region depends on the wavelength. This means that the gain changes depending on the incident light wavelength. It is therefore important to select an APD with spectral response
Characteristics that match your application

4. Terminal Capacitances

APDs have the same terminal capacitance characteristics as those of normal photodiodes. To ensure high-speed response, it is necessary to apply a reverse voltage which makes the depletion layer thicker than the penetration depth of the light into the light absorption layer. If carriers are generated outside the depletion layer, they cause problems such as slow signal decay time. Since the terminal capacitance depends on the depletion layer thickness, it can be used as a guide to find to what extent the semiconductor substrate is depleted. Unlike the gain characteristics, the terminal capacitance is not temperature-dependent. However, it does vary depending on the reverse voltage, as shown in region (1) of Figure 1-4. So use the APD at a reverse voltage that ensures a constant terminal capacitance as in region (2)

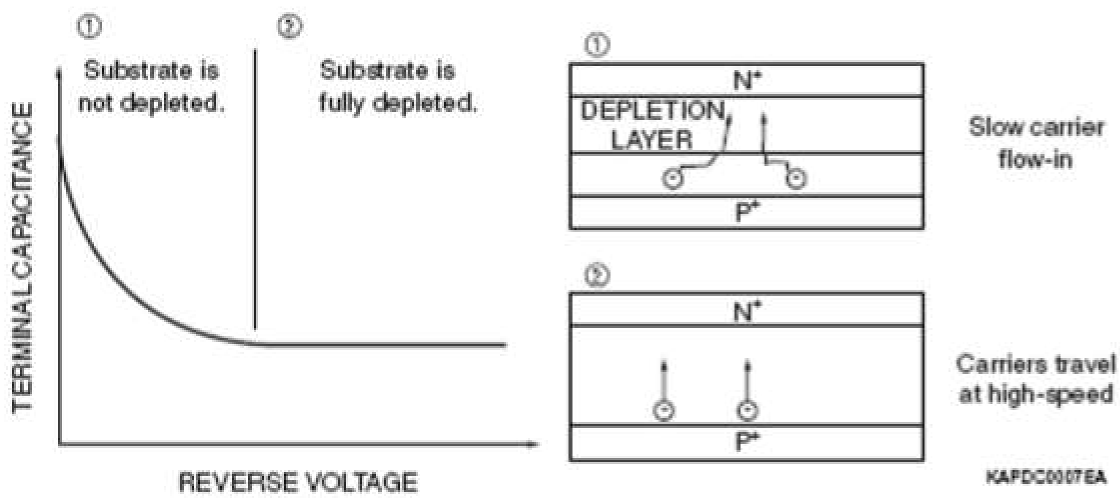


Figure 1-4 Terminal capacitances vs. reverse voltage

Background Information On PIN and APD Photodiode characteristics

Optical Detectors:

By definition photo detector converts light signals to electrical signals which can then be processed further. For fiber optic applications photo detectors works at standard wavelength at 850, 1310 and 1550 nm. Suitable photodiodes may be either PIN diodes or avalanche photo diode (APD). In either case the operating wavelength determines the material used, for example Si being employed at 800-900nm and GE or alloys of In, GA, As and P at 1310nm.

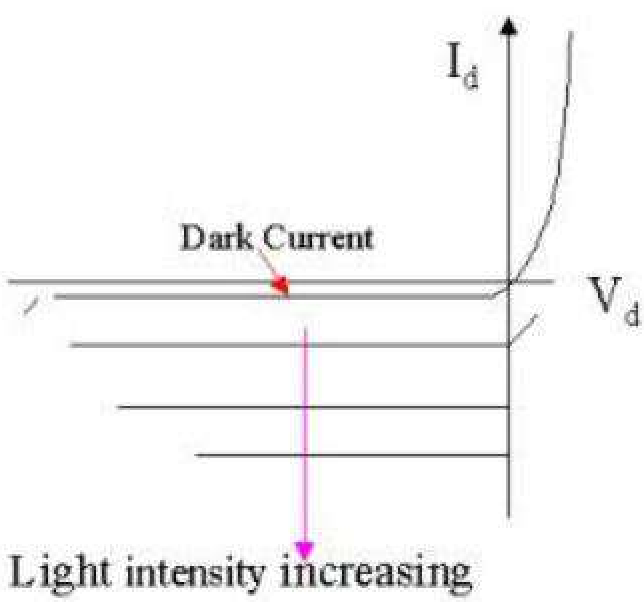
Pin diodes and APD's are variations on a basic depletion layer photodiode in which reverse current is altered by absorption of light at correct wavelength. APD's differ from pin diode in that APD's have high gain so that with the correct circuitry better sensitivity can be achieved with APD's.

Definitions for photo diode:

Quantum Efficiency: It is defined for photo diodes as the fraction of incident photons having sufficient energy to liberate electrons. The symbol used is R and by definition it is dependent on both wavelength and photodiode material.

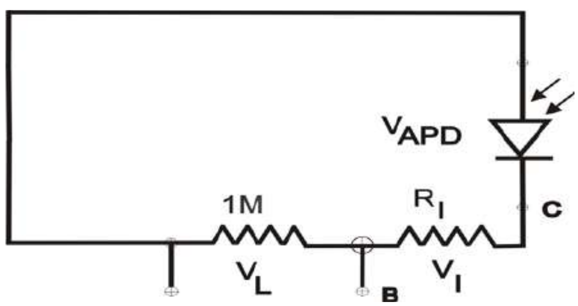
Responsivity: Responsivity of photo diode is a practical measure of output current for a given optical power input. It is defined as average output current divided by average incident optical power so its unit is A/W.

Gain: It is the multiplication of primary photon current. Gain exists in APDs only and is defined as ratio of the output current at an operating voltage to the current at low voltage where the gain is unity that is no multiplication occurs. In effect the primary photon current is multiplied by collision ionization in a high field area. A typical gain characteristic is shown below.

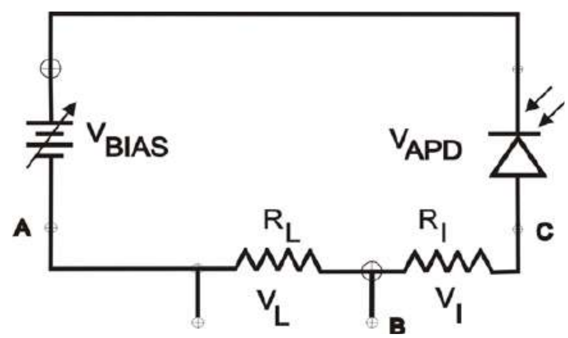


Dark Current: In absence of light a small dark current flows in a photo diode which is caused by leakage in the reverse biased photodiode. It has a very small effect in the performance of a receiver in terms of sensitivity and is ignored in any further analysis. It has been shown that dark current less than 0.1nA have very little effect. Finally photodiodes normally exhibits rise and fall times less than 1nSec.In APD's depletion capacitance increases rapidly below a certain reverse bias voltage, so to maintain fast rise and fall times a minimum bias voltage is maintained.

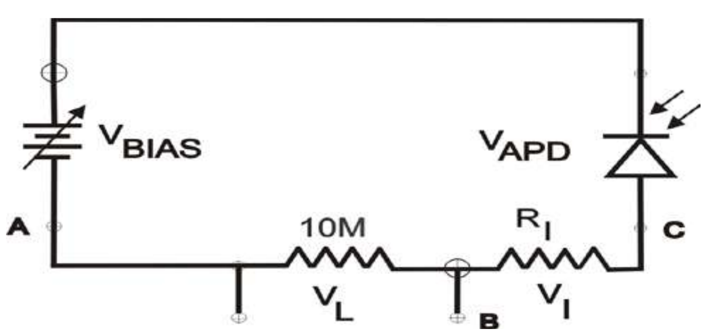
Experimental setup



Zero bias configuration



Reverse bias configuration



APD With leakage characteristics configuration

PROCEDURE:

- Connect the APD power supply properly to the module using the DIN-DIN cable provided with the power supply. Set the bias switch to the zero bias configuration (Bias switch moved to the top most position). Turn the bias voltage varying pot in the APD module to its minimum position and switch ON the module. The Zero bias LED lights up.
- Keeping the pot in its minimum position before switching ON ensures that the high voltage is not applied quickly.
- The photodiode is given no bias voltage. The current induced by the photo-detector due to the incident optical power on to it, flows through the load resistor.
- APD with zero bias configuration
  - Put 1Mohm resistor across V_L.
  - Set the Power source in CW mode and to give max output power (refer Benchmark power source manual on how to adjust the power). Connect 1m ST-ST patch cord between source and meter and measure this optical power P and adjust the power in source such that it reads -18dBm approx. Note down this power and connect this patch cord between APD and power source. Measure the voltage across V_L.
  - Vary the optical power P from –18dBm to –40dBm approx in steps of 5dBm. To reduce the power more than what the power source can attenuate, remove the ST connector of the patch cord slightly that is connected to the power source.

$$I_L = V_L / 1x10^6$$

  - Plot I_L versus power.

Reverse bias condition

- Connect the APD power supply properly to the module using the DIN-DIN cable provided with the power supply. Set the bias switch to the reverse bias configuration (Bias switch moved to the middle position). Turn the bias voltage varying pot in the APD module to its minimum position and switch ON the module. The reverse bias LED lights up.

- Keeping the pot in its minimum position before switching ON ensures that the high voltage is not applied quickly.

- The module at the reverse bias configuration switches the photodiode to a basic configuration. This mode of operation is also called as Photoconductive operation. The photodiode is given reverse bias voltage. The current induced by the photodiode, due to the incident optical power on to it, flows through the load resistor.

- Put 1K resistor across V_L. Set the Power source in CW mode and to give max output power. Connect 1m ST-ST patch cord between source and meter and measure this optical power P and adjust the power in source such that it reads -18dBm approx. Note down this power and connect this patch cord between APD and power source. Set the APD bias to 10V by adjusting the bias pot. Measure the voltage across V_L.
- Vary the bias voltage from 10V to 140V or to the max voltage that is possible in steps of 20V approx and note down the voltage across V_L and tabulate.

Power P= -18dBm

$I_R = V_L / 1 \times 10^3$

- Plot the graph V_{Bias} Vs I_R
- In the above table, for each value of the bias voltage and current calculate the value of the Responsivity R_λ with the formula given below. **$R_\lambda = V_L / R_L P_S$ A/W**

  Where P_S is the optical power in W
- Calculate the value of the quantum efficiency from the formula $\eta = [R_\lambda h \nu / e] \times 100$

Where h is the Planck's constant = 6.64×10^{-34} JS

ν is the frequency of the incident photons

$= C/\lambda = 3 \times 10^8 / 850 \times 10^{-9}$ Hz

e is the electric charge = 1.6×10^{-19} Coulombs

APD Leakage characteristics

- One among the important characteristics of a photo-detector is its leakage characteristics when it is reverse biased. Since the leakage current (or the dark current) through the photo-detector is normally very less, a high value of R_L is recommended to use in the module at the reverse bias configuration.
- Connect the APD power supply properly to the module using the DIN-DIN cable provided with the power supply. Set the bias switch to the reverse bias configuration (Bias switch moved to the middle position). Turn the bias voltage varying pot in the APD module to its minimum position and switch ON the module. The reverse bias LED lights up.
- Put 10 M ohm resistor across V_L.
- Close the APD with a dummy connector supplied with the module. This is done to avoid stray light falling on the Photodiode.
- Measure the voltage V_L for various values of bias voltages from 10V to 140V or to the maximum voltage that is possible in steps of 20V and tabulate the values.

OBSERVATION:

Zero bias

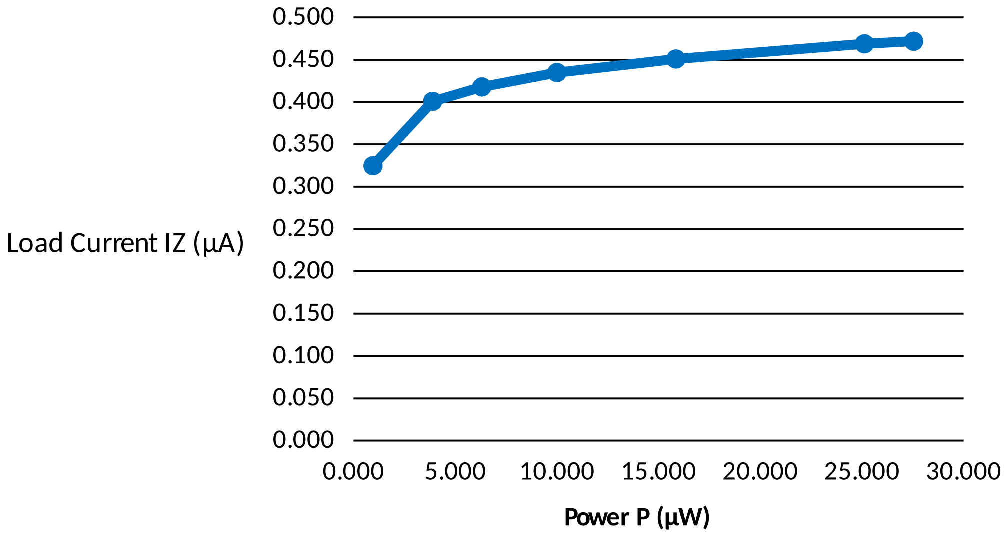
P-I Characteristics

PowerPo (dBm)	Power in µW	V_L in V	Iz in µA
-30.2	.955	.325	.325
-30.2	.955	.401	.401
-30.2	.955	.418	.418
-30.2	.955	.435	.435
-30.2	.955	.451	.451
-30.2	.955	.469	.469

RL = 1 MΩ

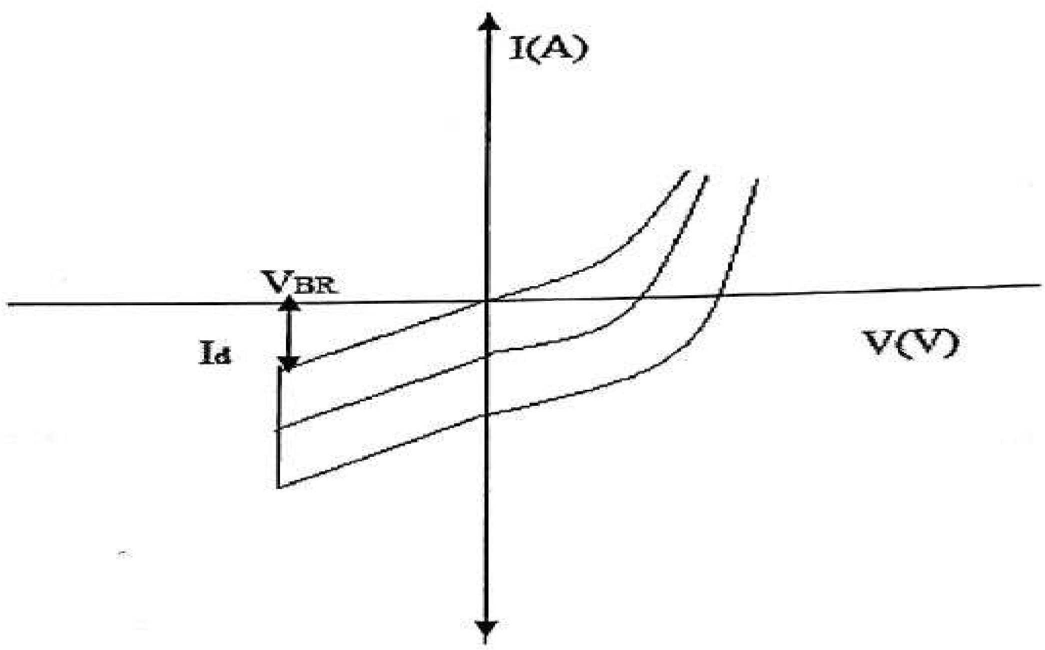
Iz = V_L/1000000

Sample graph



Reverse bias

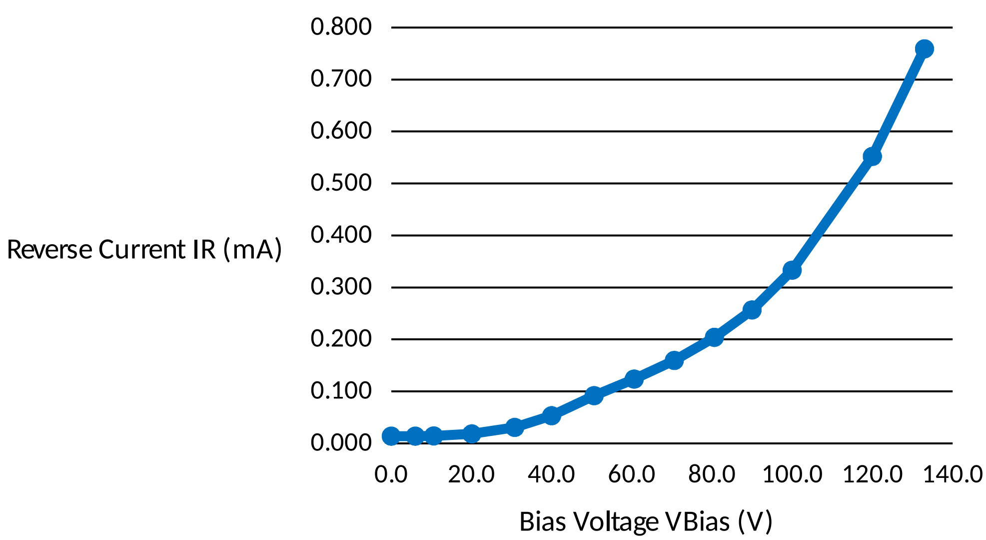
V-I characteristics



Power launched =-18.5 dB

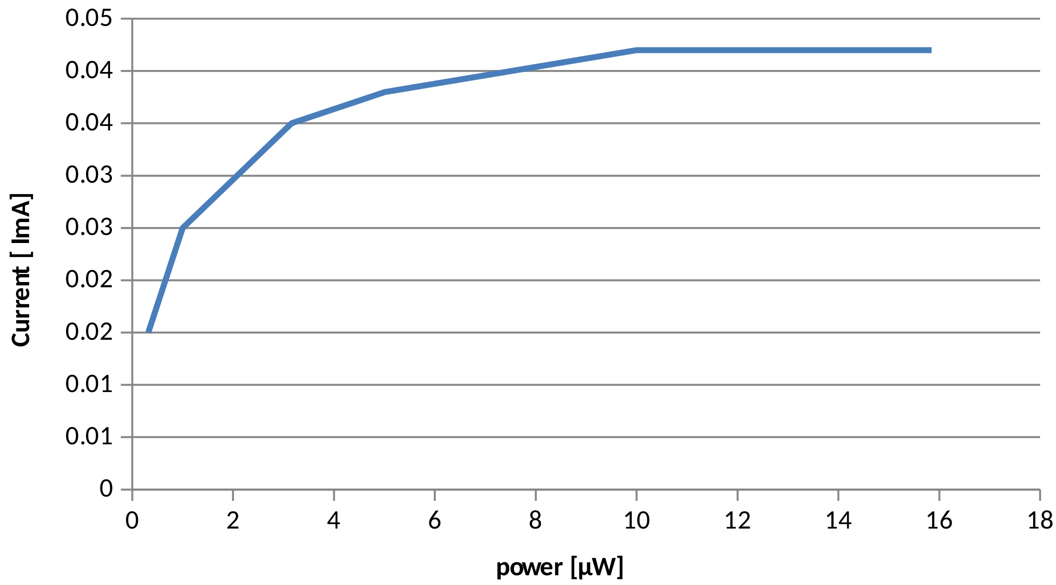
R = 10 kΩ
Ir = V_L/10000

Bias Voltage V_{Bias} (V)	V_L (V)	I_R (mA)
0.0	0.139	0.014
6.0	0.139	0.014
10.6	0.143	0.014
20.1	0.182	0.018
30.8	0.307	0.031
40.0	0.532	0.053
50.6	0.918	0.092
60.6	1.237	0.124
70.6	1.595	0.160



P- I characteristics

power	VR	power [µW]	I [mA]
-35	0.15	0.32	0.015
-30	0.25	1	0.025
-25	0.35	3.16	0.035
-23	0.38	5.01	0.038
-20	0.42	10	0.042
-19	0.42	12.59	0.042



Responsivity and efficiency

V_{BIAS} (V)	V_L (V)	I_R (mA)	Power (dBm)	Power (W)	R_L (Ω)	Rλ (A/W)

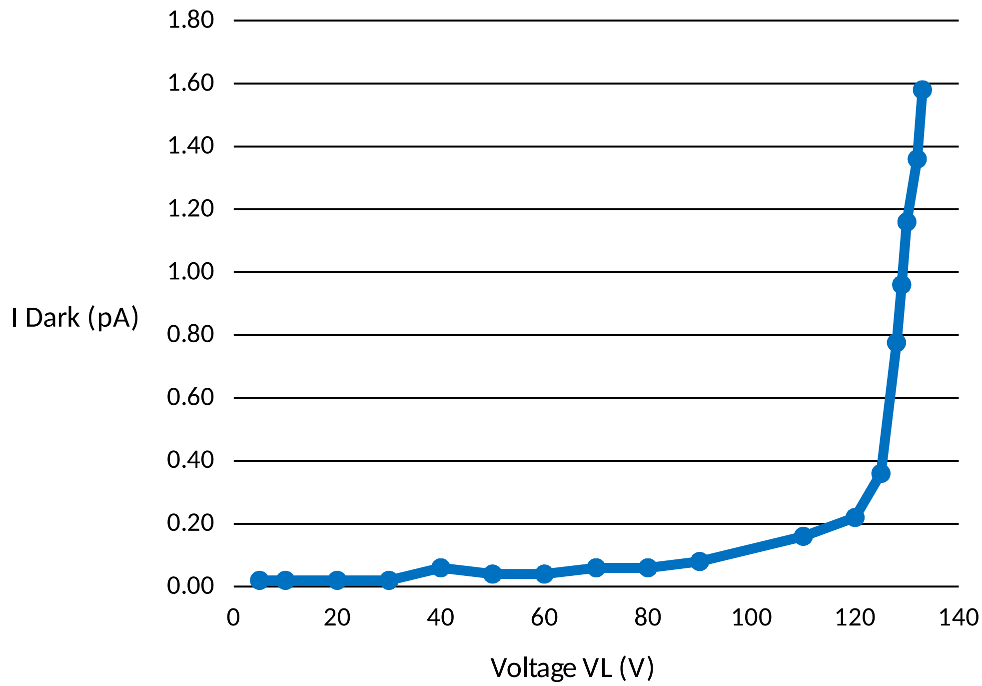
Average responsivity =…………..

Efficiency η =…………………….

Leakage characteristics

R	R_L ‖ R_M	5 MΩ
R_L	Load resistant	10 MΩ
R_M	Multimeter resistant	10 MΩ

V_{Bias} (V)	Voltage V_L (V)	I_{Dark} (pA)
5	0.1	0.02
10	0.1	0.02
20	0.1	0.02
30	0.1	0.02
40	0.3	0.06
50	0.2	0.04
60	0.2	0.04
70	0.3	0.06
80	0.3	0.06
90	0.4	0.08
110	0.8	0.16
120	1.1	0.22
125	1.8	0.36
128	3.9	0.78
129	4.8	0.96
130	5.8	1.16
132	6.8	1.36
133	7.9	1.58



RESULT:

Studied the Characteristics of Avalanche Photo Diode (APD) and measured the responsivity.

11. MEASUREMENT OF FIBER CHARECTERISTICS, FIBER DAMAGE AND SPLICE LOSS/CONNECTOR LOSS BY OTDR.

AIM:

To perform link analysis fiber characteristics, fiber damage and splice loss using OTDR

EQUIPMENTS REQUIRED:

OTDR, dummy fiber

THEORY:

Optical test set used to measure fiber attenuation, loss, length, splice loss, reflectance, and distance to an event. It is a unique fiber test set in that it measures fiber with access to only one end of the fiber. It also measures the distance to a point along the fiber. OTDRs use a phenomenon called backscatter as the basis for their operation. An OTDR sends a pulse out into the fiber and impurities in the fiber cause a small amount of power from the pulse to be returned to the OTDR in a process called backscatter. By timing the returned energy to the OTDR, the distance into the fiber can be determined. The result is a power versus distance plat provided as output by the OTDR.

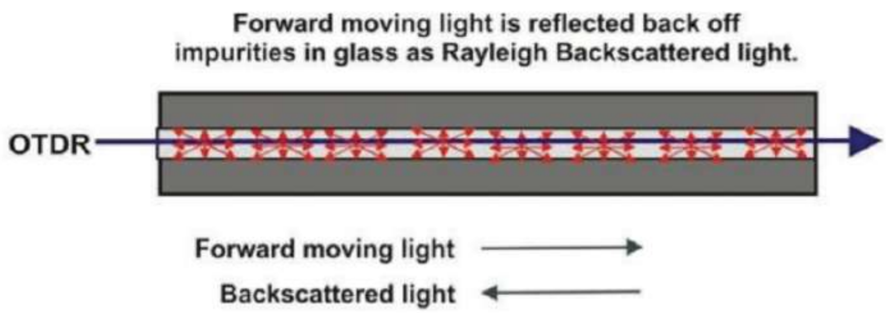
Technical Parameters

Attenuation Coefficient: Attenuation coefficient is the parameter that characterizes the fiber loss per unit length. If is typically expressed as dB/km or dB/kft. The slope of the linear portion of the OTDR fiber trace is equal to the attenuation coefficient of the fiber being measured.

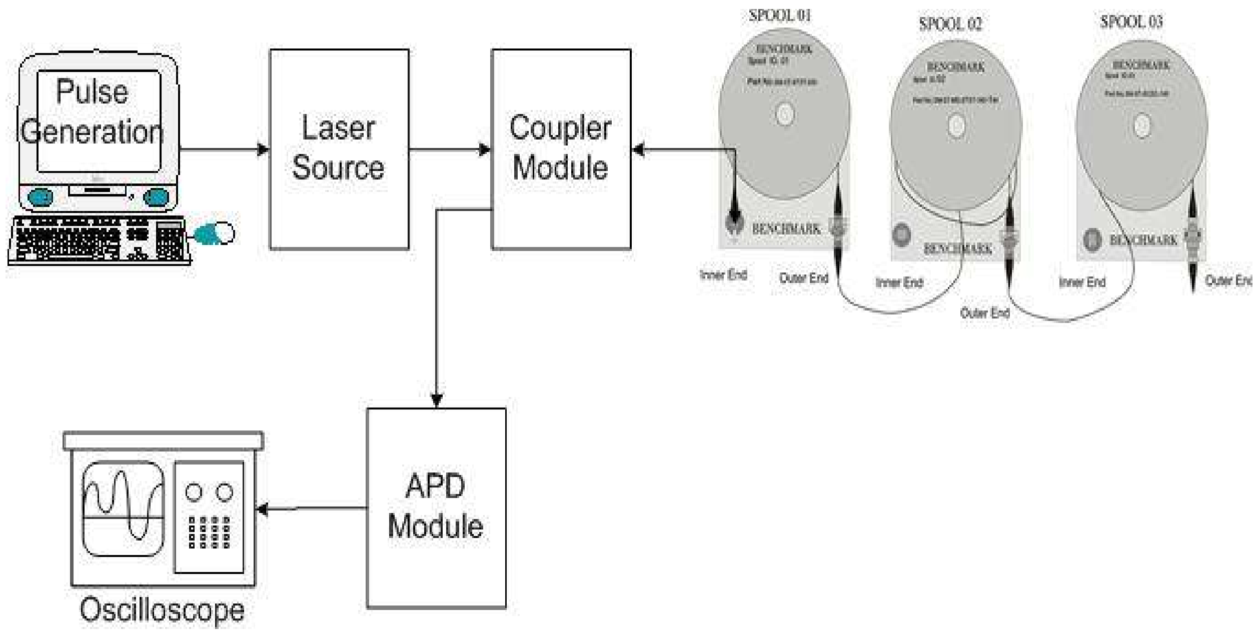
Splice: A splice is a connection between two optical fibers. Splices typically exhibit some optical loss. On an OTDR, a non-reflective splice, such as what you would get from a fusion splice, looks like a sudden drop off in optical power. The OTDR fiber trace of a non-reflective spice appears similar to a water fall. The OTDR fiber trace of a reflective splice, typical of what one might get from a mechanical connector, is a spike equivalent in height to the reflectance of the connection followed by a trace that curve asymptotically to the linear slope of the fiber following the mechanical connector.

Dead Zone: OTDRs exhibit a phenomenon that results from having their receiver over driven by the reflective power that returns from a reflective event and from the fact that the fiber pulse has a finite length that takes a finite amount of time to pass over a fiber event. There are two types of dead zones that are often discussed:

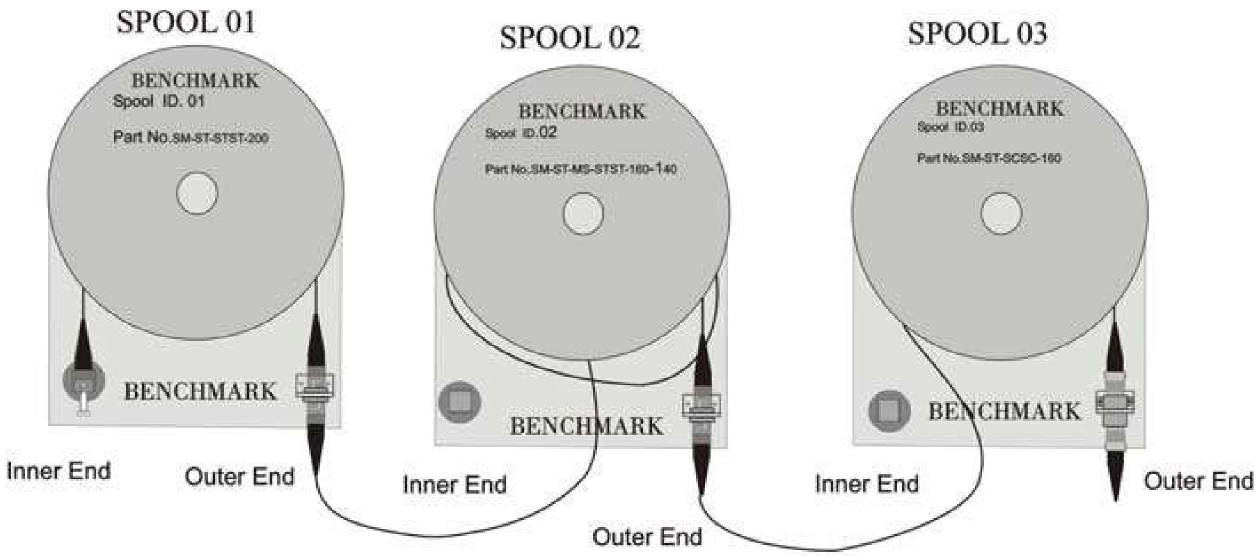
- Event dead zone: The minimum distance required for adjacent reflective events to be identified by an OTDR as two distinct events. If the two events are within the event dead zone, they appear as one event, an elongated version of the first event. Two versions of the event dead zone are often used, non-reflective and reflective event dead zone, depending upon the reflectance of the event being discussed.
- Attenuation dead zone: The minimum distance required, after a reflective event, for an OTDR to recover sufficiently to measure a reflective or non-reflective event loss accurately. If an event occurs within the attenuation dead-zone, it may be detected as a second event, but its distance or its loss cannot be accurately determined because it is within the zone in which the fiber trace is recovering from the first event to asymptotically approach the backscatter level of the fiber beyond the second event in question. The dead-zone of an event depends upon:
  - The loss of the event - the greater the loss the greater the dead zone.
  - The reflectance of the event - the greater the reflectance of the event used, the greater the dead zone.
  - Energy within the OTDR pulse - the greater the energy (pulse width) of the event selected to be used by the OTDR, the greater the dead zone.



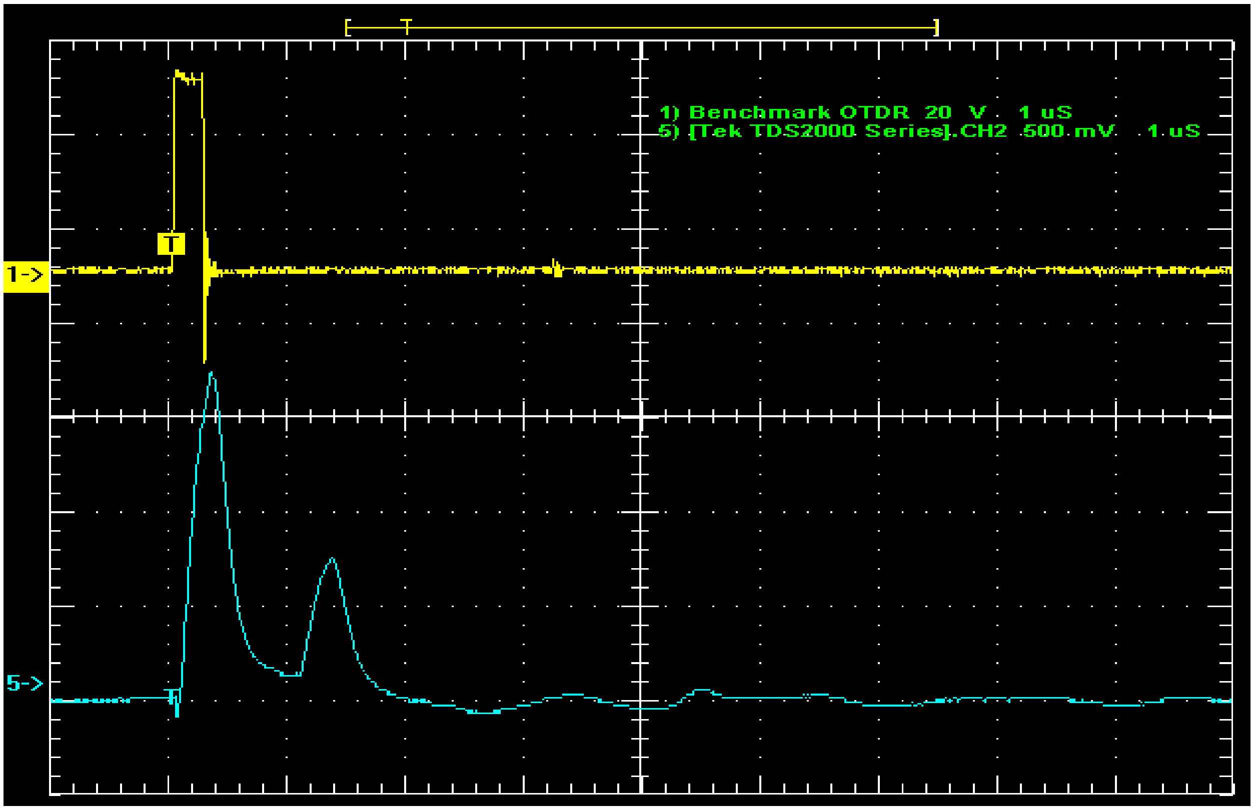
Schematic Drawing of the Backscatter Phenomena upon Which OTDRs Use to Make Measurements



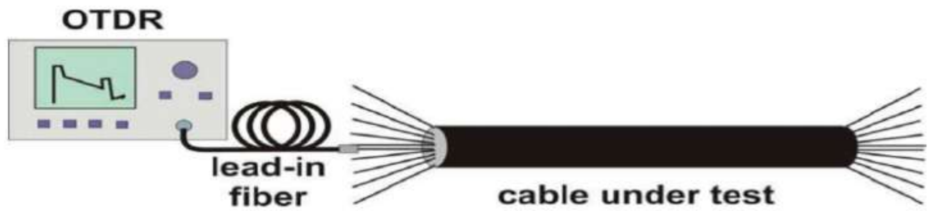
Building block of OTDR



Set up of optical fiber events

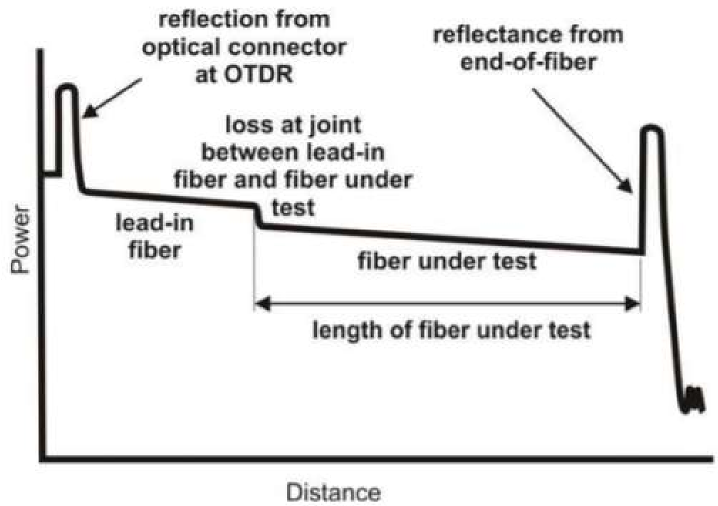


Sample graph of Benchmark Optical fiber event setup



PROCEDURE:

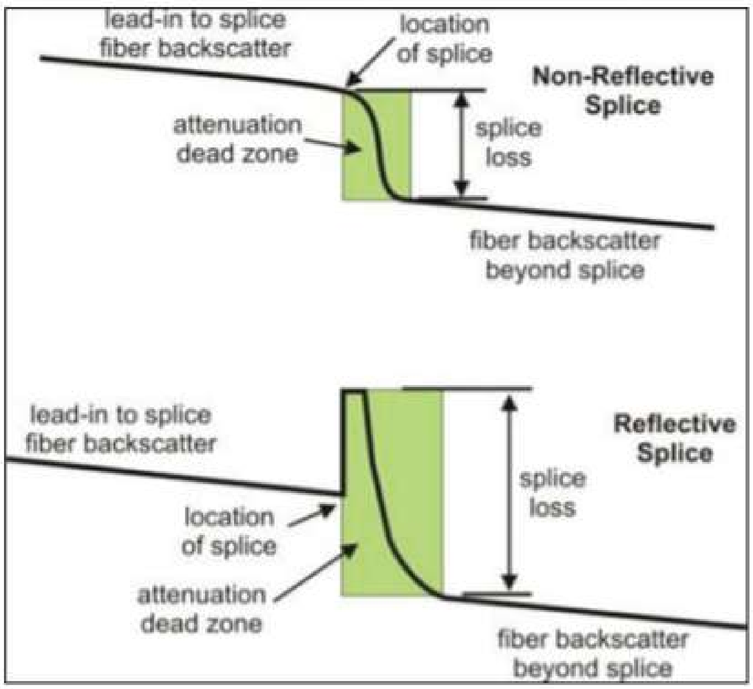
Connecting Dummy Fibers / Pigtails to OTDR: Clean optical connector in end of lead-in fiber that will mate with the OTDR using isopropanol and lint free wipers. Connect it to the OTDR output so that a fiber trace can be observed. A square peak on the fiber trace will mark the start of the trace. Next to this peak OTDR traces should be a smooth with a continuous slope. Adjust the connector to obtain the OTDR trace as shown in figure below



Typical OTDR trace

Splice loss measurement

OTDRs launch short duration light pulses into a fiber and then measures the optical power returned from this pulse as it travels down the fiber versus time from the original launching of the pulse much like radar. All measurements are made from the launch end of the fiber being tested. The returned optical signal is digitized, converted to logarithmic units of power (dBs), and then, displayed with the time base translated to fiber distance. To improve the signal-to-noise ratio of the received signal, the returned signal from many consecutive pulses is averaged. The returned signal consists of backscattered light from along the fiber, and reflected light from “events” such as refractive index discontinuities at fiber joints, breaks, and ends. Optical loss between two points on the fiber can be indirectly determined by measuring the difference in the returned backscatter power between the two points in question.

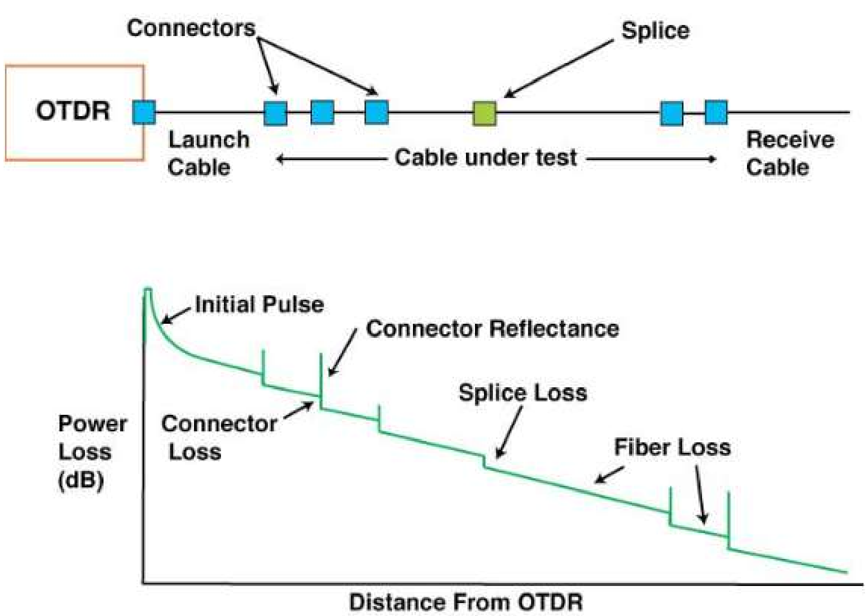


Measurement of splice loss from OTDR fiber trace

Fiber damage detection

- Choose the nearest joint or termination to find the exact location where fault has occurred and connect a dummy fiber to the output adaptor of OTDR.
- Start measurement in real time.
- Set/place marker “A” at the end of trace & zoom linear portion of trace.

- Bend another end of dummy fiber so that perfect square pulse reflection will be observed on trace.
- Set marker "A" as close as possible to the reflection pulse & note down distance reading.
- Splice this dummy with faulty fiber using fusion or mechanical splicing & detect fault location
- Set/place marker "B" as close as possible to the fiber fault reflection.



- Note the distance reading of marker "B".
- Optical distance of fault from the point of test is calculated as follows:

Optical Fault Distance = distance of marker (B) - distance of marker (A).

RESULT:

Fiber characteristics splice loss and connector losses are measured from the graph displayed in the OTDR.

REFERENCES

- Fiber Optic Reference Guide – **David Goff**
- Optical fiber communications – **Gerd Keiser**
- Optical Fiber Communications- 3rd- edition **John M .Senior**
- Fiber Optic Communications systems,- **Govind P.Agrawal**