Department of Pure and Applied Physics

M.Sc. Electronics III semester academic year 2022-23

Core-9: Optoelectronics Devices Lab
Course Code: PLPCLT3
Credit: 2 (0+0+2)
Name of the experiments

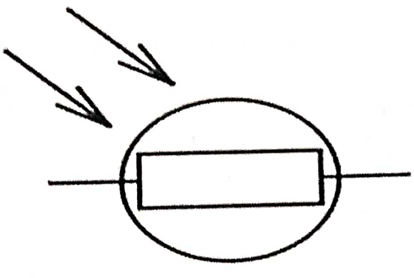
1. To study the I-V Characteristics of LED
2. To study the Voltage Vs. Intensity of a semiconductor laser Diode
3. To characterize the laser grating using semiconductor laser diode
4. To verify the law of Malus for plane polarized light.
5. To find out the characteristics of a photodetector.
6. To characterize the solar cell and find out the FF and Efficiency of a solar Cell.
7. To Study of the Electro-optic Effect using Semiconductor laser diode.
8. To measure the numerical aperture of an optical fiber. Using Semiconductor laser diode.

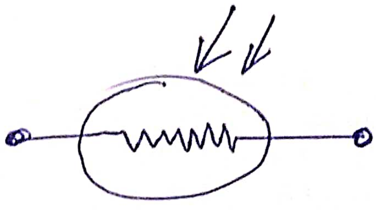
Aim: - **Study the characteristics of opto electronic devices, light dependent Resistor (LDR) and light Emitting Diode (LED).**

Apparatus: - one DC regulated power supply of 0-3 volts, light dependent Resistor (LDR) and light Emitting Diode (LED). Voltmeter 0-3 volt DC, DC miliammiter, and one lamp with stand connection wires etc.

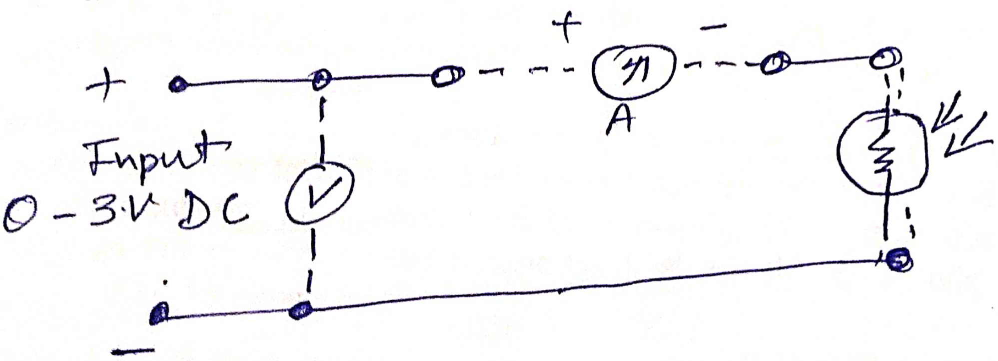
Theory:-

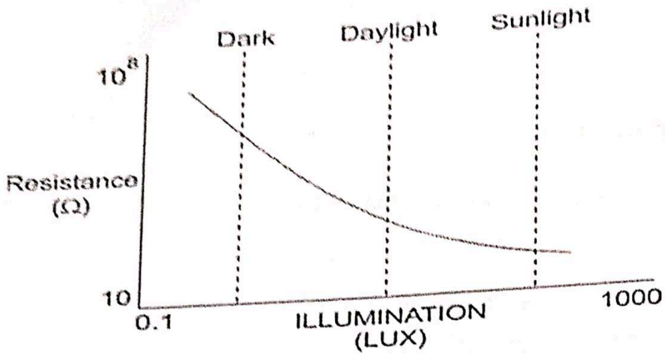
1. A ***Light Dependent Resistor*** (LDR) or a photo resistor is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices. They are also called as photo conductors, photo conductive cells or simply photocells. They are made up of semiconductor materials having high resistance. There are many different symbols used to indicate a **LDR**, one of the most commonly used symbol is shown in the figure below. The arrow indicates light falling on it





A **light dependent resistor** works on the principle of photo conductivity. Photo conductivity is an optical phenomenon in which the materials conductivity is increased when light is absorbed by the material. When light falls i.e. when the photons fall on the device, the electrons in the valence band of the semiconductor material are excited to the conduction band. These photons in the incident light should have energy greater than the band gap of the semiconductor material to make the electrons jump from the valence band to the conduction band. Hence when light having enough energy strikes on the device, more and more electrons are excited to the conduction band which results in large number of charge carriers. The result of this process is more and more current starts flowing throgh the device when the circuit is closed and hence it is said that the resistance of the device has been decreased. This is the most common **working principle of LDR.**





Procedure:-

1. Connect the output of DC power supply (0-3 VDC) to the input of the LDR circuit. Also connect voltmeter, current meter and LDR in the circuit through patch cords shown by doted lines.
2. Place the lamp holder and LDR on a graduated wooden stand opposite to each other. Connect the lamp to AC mains and focus the light on LDR. Select the range of current meter to 5mA.
3. Switch on the instrument (power supply unit) using ON/OFF toggle switch provided on the front panel.
4. Now increase the power supply voltage in small step and every time note down the voltage & current in observation table. Calculate the registance valu of LDR by using formula R = V/I
5. Vary the distance (d) between LDR & light source and repeat the experiment again.
6. Plot a graph between resistance (R) vs Distance (d2 ,SQURE).
7. also note down the current (mA) for different distances between LDR & light source for fixed voltage.

Observation table for LDR

S,no.	Distance of lamp from LDR d cm	Voltmeter reading v volt	Milliammeter reading (I) mA	Resitance of LDR R = V/I	D2 cm2
1					
2					
3					

2. Light Emitting Diode (LED).

They are the most visible type of diode that emit a fairly narrow bandwidth of either visible light at different colored wavelengths, invisible infra-red light for remote controls or laser type light when a forward current is passed through them.

The "Light Emitting Diode" or LED as it is more commonly called, is basically just a specialized type of diode as they have very similar electrical characteristics to a PN junction diode. This means that an LED will pass current in its forward direction but block the flow of current in the reverse direction.

Light emitting diodes are made from a very thin layer of fairly heavily doped semiconductor material and depending on the semiconductor material used and the amount of doping, when forward biased an LED will emit a colored light at a particular spectral wavelength.

When the diode is forward biased, electrons from the semiconductors conduction band recombine with holes from the valence band releasing sufficient energy to produce photons which emit a monochromatic (single color) of light. Because of this thin layer a reasonable number of these photons can leave the junction and radiate away producing a colored light output.

light emitting diode construction

LED Construction

Then we can say that when operated in forward biased direction Light Emitting Diodes are semiconductor devices that convert electrical energy into light energy.

The construction of a Light Emitting Diode is very different from that of a normal signal diode.

The PN junction of an LED is surrounded by a transparent, hard plastic epoxy resin hemispherical shaped shell or body which protects the LED from both vibration and shock.

Surprisingly, an LED junction does not actually emit that much light so the epoxy resin body is constructed in such a way that the photons of light emitted by the junction are reflected away from the surrounding substrate base to which the diode is attached and are focused upwards through the domed top of the LED, which itself acts like a lens concentrating the amount of light. This is why the emitted light appears to be brightest at the top of the LED.

However, not all LEDs are made with a hemispherical shaped dome for their epoxy shell. Some indication LEDs have a rectangular or cylindrical shaped construction that has a flat surface on top or their body is shaped into a bar or arrow. Generally, all LED's are manufactured with two legs protruding from the bottom of the body.

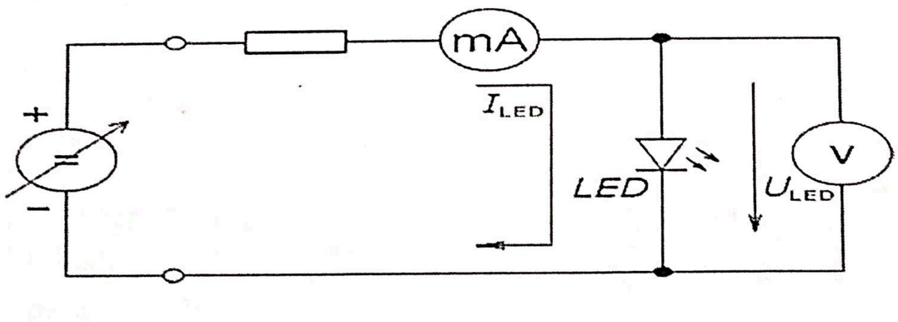
Also, nearly all modern light emitting diodes have their cathode, (–) terminal identified by either a notch or flat spot on the body or by the cathode lead being shorter than the other as the anode (+) lead is longer than the cathode (k).

Unlike normal incandescent lamps and bulbs which generate large amounts of heat when illuminated, the light emitting diode produces a "cold" generation of light which leads to high efficiencies than the normal "light bulb" because most of the generated energy radiates away within the visible spectrum. Because LEDs are solid-state devices, they can be extremely small and durable and provide much longer lamp life than normal light sources.

Light Emitting Diode Colours

So how does a light emitting diode get its colour. Unlike normal signal diodes which are made for detection or power rectification, and which are made from either Germanium or Silicon semiconductor materials, **Light Emitting Diodes** are made from exotic semiconductor compounds such as Gallium Arsenide (GaAs), Gallium Phosphide (GaP), Gallium Arsenide Phosphide (GaAsP), Silicon Carbide (SiC) or Gallium Indium Nitride (GaInN) all mixed together at different ratios to produce a distinct wavelength of colour.

Different LED compounds emit light in specific regions of the visible light spectrum and therefore produce different intensity levels. The exact choice of the semiconductor material used will determine the overall wavelength of the photon light emissions and therefore the resulting colour of the light emitted.



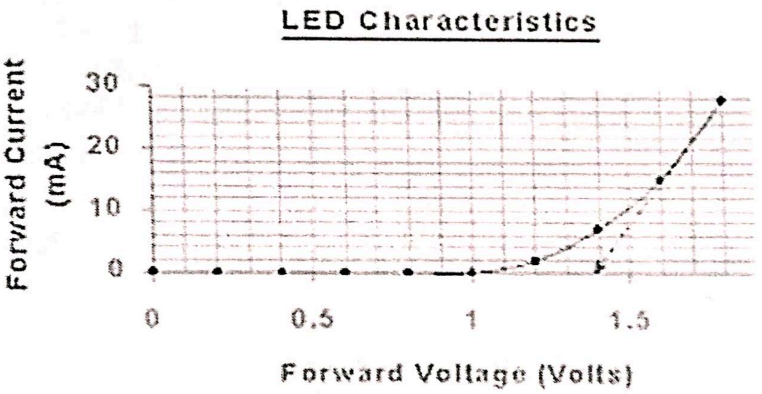
Procedure:-

1. Connect the output of DC power supply (0-3 VDC) to the input of the LED circuit. Also connect voltmeter, current meter in the circuit through patch cords shown by doted lines.

2. Switch on the instrument (power supply unit) using ON/OFF toggle switch provided on the fron panel.
3. Now increase the power supply voltage in small step and every time note down the voltage & current in observation table.
4. Plot a graph between voltage and current by taking voltage along X axis and current along Y axis.

Observation table for LED:-

s.no.	Forward voltage (V)	Forward current (I)
1		
2		
3		
4		
5		



Result:- **1. forward resistance of LDR is ……………and forward resistance of LED is…….**
2 Voltage …… & current ……… LED start Glow, Voltage …… & current ……. LED fully Glow.

Precautions:-
1. Firstly read about complete experiment then perform.
2. Connect circuit properly according to diagram.
3. Check connecting wires before use.
4. Connect current meter in series only.

Aim:

To determine slit width of single slit by using semiconductor Laser.

Apparatus:

Semiconductor laser, Single Slit, Double Slit, Screen, Scale, tape etc.

Theory:

If the waves have the same sign (are *in phase*), then the two waves constructively interfere, the net amplitude is large and the light intensity is strong at that point. If they have opposite signs, however, they are *out of phase* and the two waves destructively interfere: the net amplitude is small and the light intensity is weak. It is these areas of strong and weak intensity, which make up the interference patterns we will observe in this experiment. Interference can be seen when light from a single source arrives at a point on a viewing screen by more than one path. Because the number of oscillations of the electric field (wavelengths) differs for paths of different lengths, the electromagnetic waves can arrive at the viewing screen with a *phase difference* between their electromagnetic fields. If the Electric fields have the same sign then they add *constructively* and increase the intensity of light, if the Electric fields have opposite signs they add *destructively* and the light intensity decreases.

Diffraction at single slit can be observed when light travels through a hole (in the lab it is usually a vertical *slit*) whose width, *a*, is small. Light from different points across the width of the slit will take paths of different lengths to arrive at a viewing screen (Figure 1). When the light interferes destructively, intensity minima appear on the screen. Figure 1 shows such a diffraction pattern, where the intensity of light is shown as a graph placed along the screen.

For a rectangular slit it can be shown that the minima in the intensity pattern fit the formula

$$a\sin\theta = m\lambda$$

where *m* is an integer (±1, ±2, ±3.....), *a* is the width of the slit, λ is the wavelength of the light and θ is the angle to the position on the screen. The m^{th} spot on the screen is called the m^{th} order minimum. Diffraction patterns for other shapes of holes are more complex but also result from the same principles of interference.

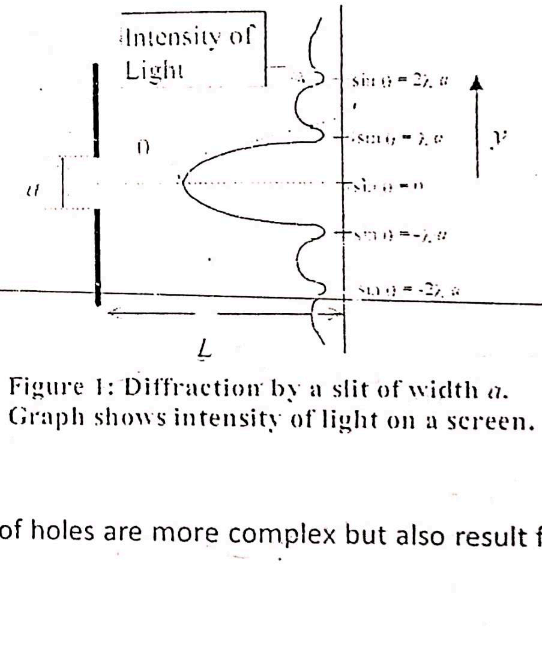


Figure 1: Diffraction by a slit of width *a*. Graph shows intensity of light on a screen.

Procedure:

Diffraction at single slit

The diffraction plate has slits etched on it of different widths and separations. For this part use the area where there is only a single slit.

For two sizes of slits, examine the patterns formed by single slits. Set up the slit in front of the laser. Record the distance from the slit to the screen, *L*. For each of the slits, measure and record a value for *y* on the viewing screen corresponding to the center of a dark region. Record as many distances, *y*, for different values of *m* as you can. Use the largest two or three values for *m* which you are able to observe to find a value for *a*. The semiconductor laser has a wavelength of 670 nm.

Observations:

Table 1: Single slit

L = ... λ = ...6700 Å

Diffraction Order, m	Distance, y	y/L	Angle θ = ~~in radians~~ $\left(\frac{y}{L} \times \frac{180}{\pi}\right)$	$\sin\theta$	$a \left(= \frac{m\lambda}{\sin\theta}\right)$

Result : Slit width = ...

Precautions:

Look through the slit (holding it very close to your eye). See if you can see the effects of diffraction. Set the laser on the table and aim it at the viewing screen.

DO NOT LOOK DIRECTLY INTO THE LASER OR AIM IT AT ANYONE! DO NOT LET REFLECTIONS BOUNCE AROUND THE ROOM.

Pull a hair from your head. Mount it vertically in front of the laser using a piece of tape. Place the hair in front of the laser and observe the diffraction around the hair. Use the formula above to estimate the thickness of the hair, *a*. (The hair is not a slit but light diffracts around its edges in a similar fashion.) Repeat with observations of your lab partners' hair.

AIM: - Study the I-V characteristics of solar cell.

APPRATUS REQUIRED: Solar cell mounted on the front panel in a metal box with connections brought out on terminals. Two meters mounted on the front panel to measure the solar cell voltage and current. Different types of load resistances selectable using band switch also provided on the front panel. patch chords for connections. a lamp holder with 100 watt lamp.

THEORY:

The solar cell is a semiconductor device, which converts the solar energy into electrical energy. It is also called a photovoltaic cell. A solar panel consists of numbers of solar cells connected in series or parallel. The number of solar cell connected in a series generates the desired output voltage and connected in parallel generates the desired output current. The conversion of sunlight (Solar Energy) into electric energy takes place only when the light is falling on the cells of the solar panel. Therefore in most practical applications, the solar panels are used to charge the lead acid or Nickel-Cadmium batteries. In the sunlight, the solar panel charges the battery and also supplies the power to the load directly. When there is no sunlight, the charged battery supplies the required power to the load.

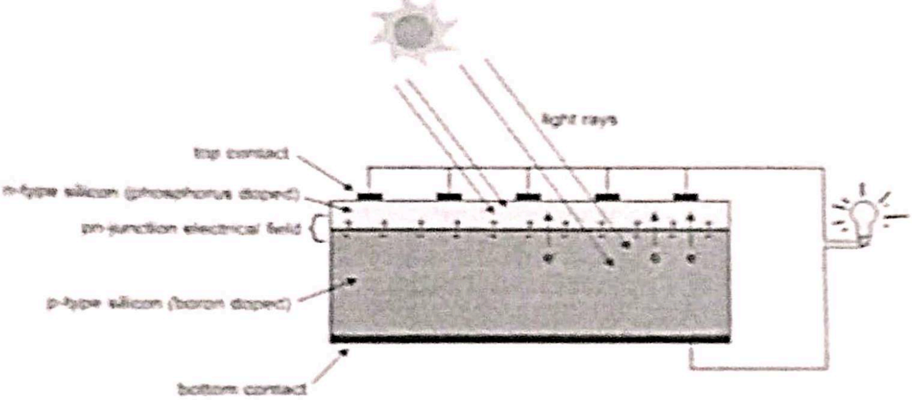
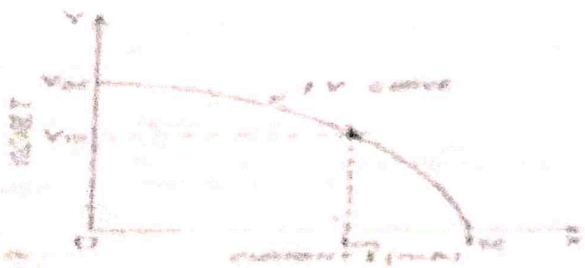


Fig. 1a Working principle of a solar cell

A solar cell operates in somewhat the same manner as other junction photo detectors. A built-in depletion region is generated in that without an applied reverse bias and photons of adequate 2 energy create hole-electrons pairs. In the solar cell, as shown in Fig. 1a, the pair must diffuse a considerable distance to reach the narrow depletion region to be drawn out as useful current. Hence, there is higher probability of recombination. The current generated by separated pairs increases the depletion region voltage (Photovoltaic effect). When a load is connected across the cell, the potential causes the photocurrent to flow through the load.

The e.m.f. generated by the photo-voltaic cell in the open circuit, i.e. when no current is drawn from it is denoted by Voc (V-open circuit). This is the maximum value of e.m.f.. When a high resistance is introduced in the external circuit a small current flows through it and the voltage decreases. The voltage goes on falling and the current goes on increasing as the resistance in the external circuit is reduced. When the resistance is reduced to zero the current rises to its maximum value known as saturation current and is denoted as Isc, the voltage becomes zero. A V-I characteristic of a photo-voltaic cell is shown in Fig. 1b.



The product of open circuit voltage Voc and short circuit current Isc is known a ideal power.
☐ Ideal Power = $V_{oc} \times I_{sc}$

The maximum useful power is the area of the largest rectangle that can be formed under the V-I curve. If V_m and I_m are the values of voltage and current under this condition, then
Maximum useful power = $V_m \times I_m$
The ratio of the maximum useful power to ideal power is called the fill factor
☐ Fill factor = $I_m X V_m / I_{oc} X I_{sc}$

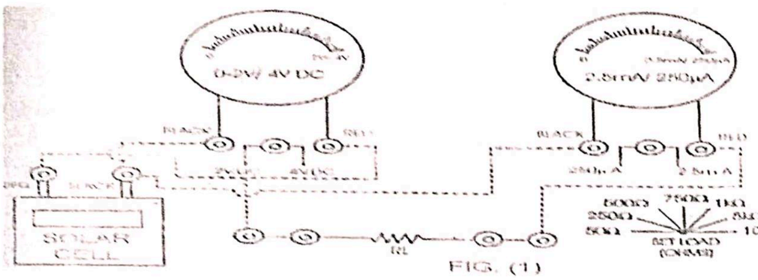


FIG. (1)

When experiment is performed with 100 Watt lamp:
1. Place the solar cell and the light source (100 watt lamp) opposite to each other on a wooden plank. Connect the circuit as shown by dotted lines (Fig. 2) through patch chords.
2. the voltmeter range to 0-3V, current meter range to 0-5 mA and load resistance (RL) to 300 -1kΩ.
3. Switch ON the lamp to expose the light on Solar Cell.
4. Set the distance between solar cell and lamp in such a way that current meter shows mA deflections. Note down the observation of voltage and current in Table 1.
5. Vary the load resistance through band switch and note down the current and voltage readings every time in observation Table .
6. Plot a graph between output voltage vs. output current by taking voltage along X-axis and current along Y-axis.

OBSERVATIONS

s. no.	Voltage	Current	Load resistance (RL)
1			
2			
3			
4			

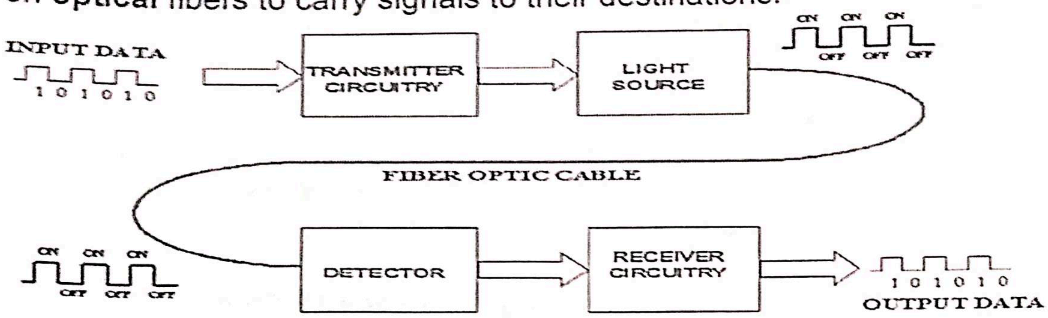
Result: ⇒

PRECAUTIONS:
1. The solar cell should be exposed to sun light before using it in the experiment.
2. Light from the lamp should fall normally on the cell.
3. A resistance in the cell circuit should be introduced so that the current does not exceed the safe operating limit.

VIVA VOICE QUESTIONS:
1. What is the difference between solar cell and a photodiode?
2. What are the types of semiconductor materials used for solar cell?
3. What is Dark current?
4. What is the difference between solar photovoltaic and solar hot water system?
5. What is the response time of photo cell?

Optical communication system :-

Optical communication is any type of **communication** in which light is used to carry the signal to the remote end, instead of electrical current.**Optical communication** relies on **optical** fibers to carry signals to their destinations.



How can optical fiber be used for communication?

Fiber optics (**optical fibers**) are long, thin strands of very pure glass about the size of a human hair. They are arranged in bundles called **optical** cables and **used** to transmit signals over long distances. **Fiber optic** data transmission systems send information over **fiber** by turning electronic signals into light.

What is optical transmitter and receiver?

A fiber **optic transmitter** is a device which includes a LED or laser source and signal conditioning electronics that is used to inject a signal into fiber. Fiber **optic**receivers capture the light from a fiber **optic** cable, decode the binary data it is sending and then convert into an electrical signal.

What is the optical source?

optical source: 1. In **optical** communications, a device that converts an electrical signal into an **optical** signal. Note: The two most commonly used **optical sources**are light-emitting diodes (LEDs) and laser diodes. 2 .

What is the line width of a laser?

The **linewidth** (or **line width**) of a **laser**, typically a single-frequency **laser**, is the**width** (typically the full **width** at half-maximum, FWHM) of its optical spectrum. More precisely, it is the **width** of the power spectral density of the emitted electric field in terms of frequency, wavenumber or wavelength.

Numerical aperture of an optical fibre:

The **Numerical Aperture** (NA) is a measure of how much light can be collected by an **optical** system such as an **optical fibre** or a microscope lens. The NA is related to the acceptance angle θa, which indicates the size of a cone of light that can be accepted by the **fibre**.

Numerical aperture is thus considered as a light gathering capacity of an **optical fibre**. **Numerical Aperture** is defined as the Sine of half of the angle of **fibre's** light acceptance cone. i.e. NA= Sin θ_a where θ_a, is called acceptance cone angle.

Acceptance Angle :
The **acceptance angle of an optical fiber** is defined based on a purely geometrical consideration (ray **optics**): it is the maximum **angle** of a ray (against the **fiber** axis) hitting the **fiber** core which allows the incident light to be guided by the core

Therefore, the fiber-optic critical angle = (**90 degrees** - physics critical angle). In an optical fiber, the light travels through the core (m1, high index of refraction) by constantly reflecting from the cladding (m2, lower index of refraction) because the angle of the light is always greater than the critical angle.

What is the cladding in fiber optics?

Cladding in **optical fibers** is one or more layers of materials of lower refractive index, in intimate contact with a core material of higher refractive index. The**cladding** causes light to be confined to the core of the **fiber** by total internal reflection at the boundary between the two.

Why refractive index of core and cladding is different?

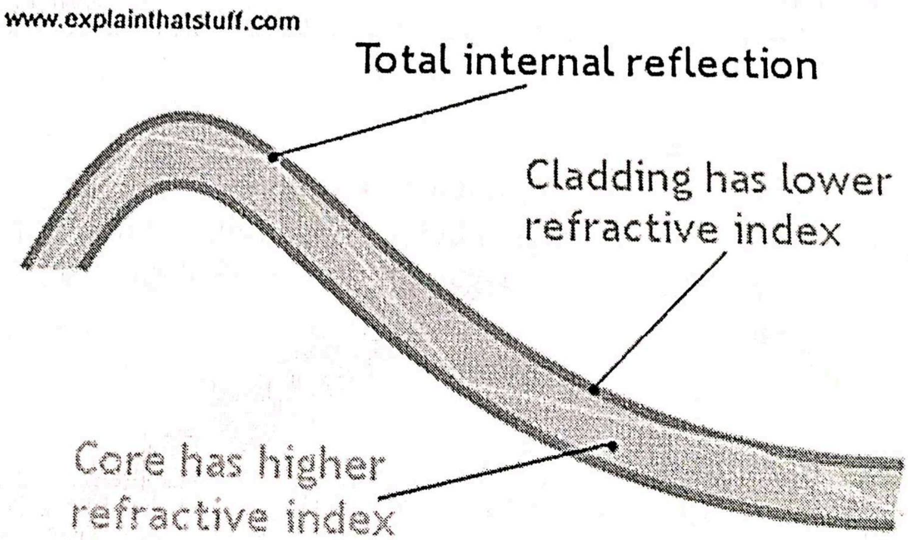
The **refractive index** of the **core**, n1, is always greater than the **index** of the**cladding**, n2. Light is guided through the **core**, and the fiber acts as an optical waveguide. ... As illustrated, a light ray is injected into the fiber-optic cable on the left.

What is the purpose of the cladding in a fiber optic cable?

The larger the core, the more light that will be transmitted into the **fiber**. **Cladding**:
The **function** of the **cladding** is to provide a lower refractive index at the core interface in order to cause reflection within the core so that light waves are transmitted through the **fiber**.

What is a fiber core?

The **core** of a conventional optical **fiber** is a cylinder of glass or plastic that runs along the **fiber's** length. The **core** is surrounded by a medium with a lower index of refraction, typically a cladding of a different glass, or plastic.



DETERMINATION OF NUMERICAL APERTURE OF OPTICAL FIBERS

OBJECTIVES:

To determine the numerical aperture of the PMMA FIBER cables included with this FO-1.

BASIC DEFINITIONS:

Numerical aperture of any optical system is a measure of how much light can be collected by the optical system. It is the product of the refractive index of the incident medium and the sine of the maximum ray angle.

$NA = n_i.\sin\theta_{max}$; Ni for air is 1, hence $NA = \sin\theta_{max}$;

For a step-index FIBER, as in the present case, the numerical aperture is given by

$N = \sqrt{(n_{core}^2 - n_{cladding}^2)}$

For very small differences in refractive indices the equation reduces to

$$NA = n_{core}\sqrt{(2\Delta)},$$

Where;

Δ is the fractional difference in refractive indices

The fiber may refer to the specifications of the PMMA FIBER given in appendix-1 and record the manufacturer's NA, $n_{cladding}$ and n_{core} and θ.

STEP-BY-STEP PROCEDURE:

(WITH BLOCK SCHEMATIC):

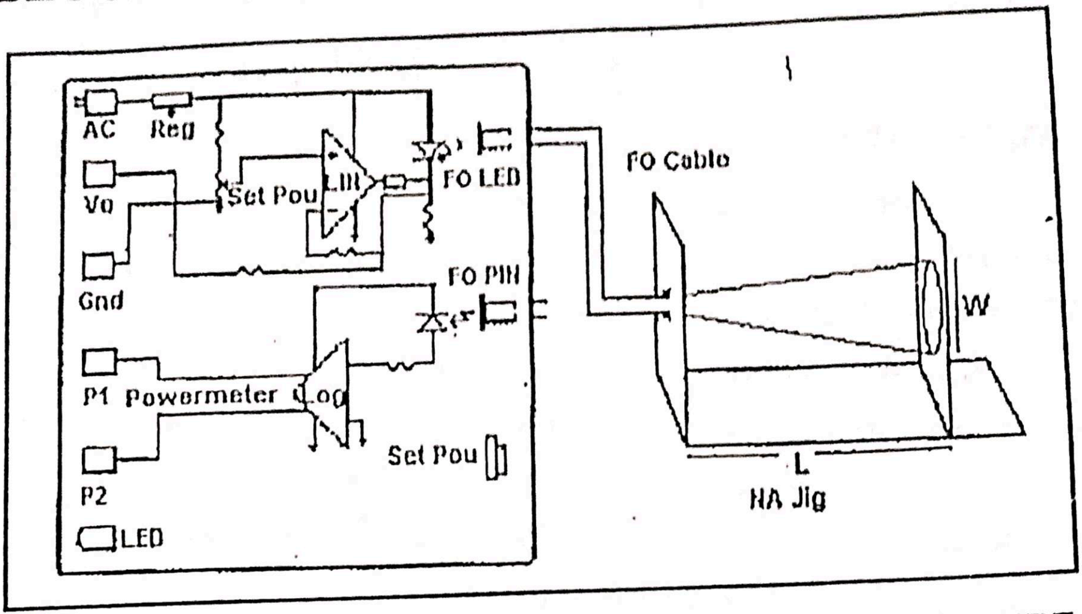


FIGURE – 2: THE SCHEMATIC OF THE NUMERICAL APERTURE MEASUREMENT SYSTEM

1. Connect one end of the Cable 1 (1-meter FO cable) to FO LED in the FIBER Optic LED driver section of FO1 and the other end to the NA Jig, as shown in figure - 2.
2. Switch On the trainer. Light should appear at the end of the FIBER on the NA Jig. Turn the **Set P_{out}** knob clockwise to set to maximum Po. The light intensity should increase.
3. Hold the white screen with the concentric circles (5, 10, 15, 20 and 25mm diameter) vertically at a suitable distance to make the red spot from the emitting FIBER coincide with the 10 mm circle. Note that the circumference of the spot (outermost) must coincide with the circle. A dark room will facilitate good contrast. Record "**L**" the distance of the screen from the FIBER end and note the diameter) of the spot. You may measure the diameter of the circle accurately with a suitable scale.
4. Compute NA from the formula;

$$NA = \sin\theta_{max} = W/\ (4L^2+W^2)^{1/2}$$

Tabulate the reading and repeat the for 15mm, 20mm and 25 mm diameters too.

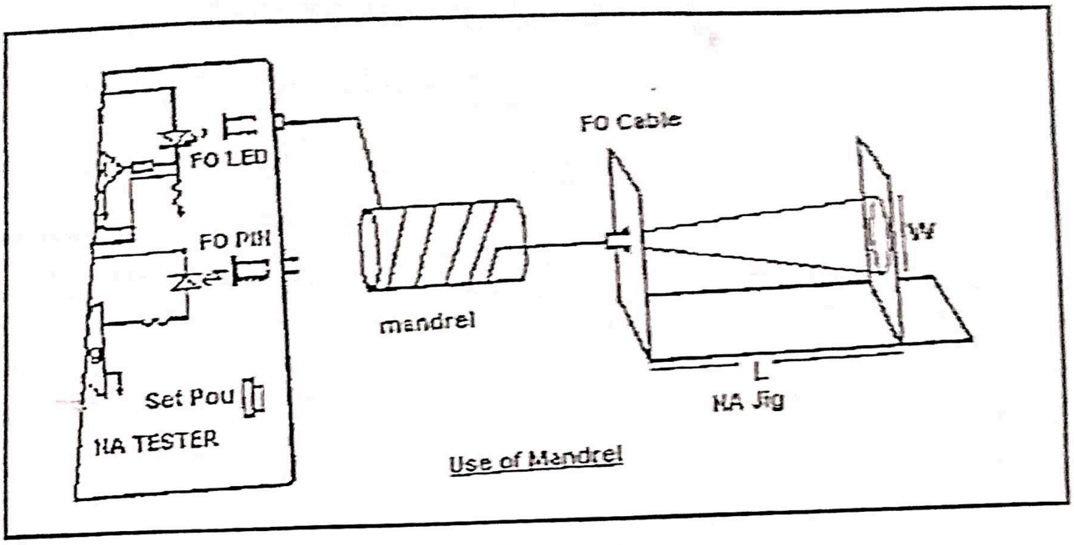


FIGURE – 3

5. In case the FIBER is under filled, the intensity within the spot may not be evenly distributed. To ensure even distribution of light in the FIBER, first remove twists on the FIBER and then wind 5 turns of the FIBER on to the mandrel as shown in figure-3. Use an adhesive tape to hold the windings in position. Now view the spot. The intensity will be more evenly distributed within the core.

TABLE -1

S.No	L (mm)	W(mm)	NA	θ (degrees)
1	10	10	0.447	26.5
2	16	15	0.423	25.0
3	20	20	0.447	26.5
4	26	25	0.432	25.64
5	30	-	-	-

$NA = \frac{W}{\sqrt{(4L^2+W^2)}}$ $\theta = \sin^{-1}(0.447)$

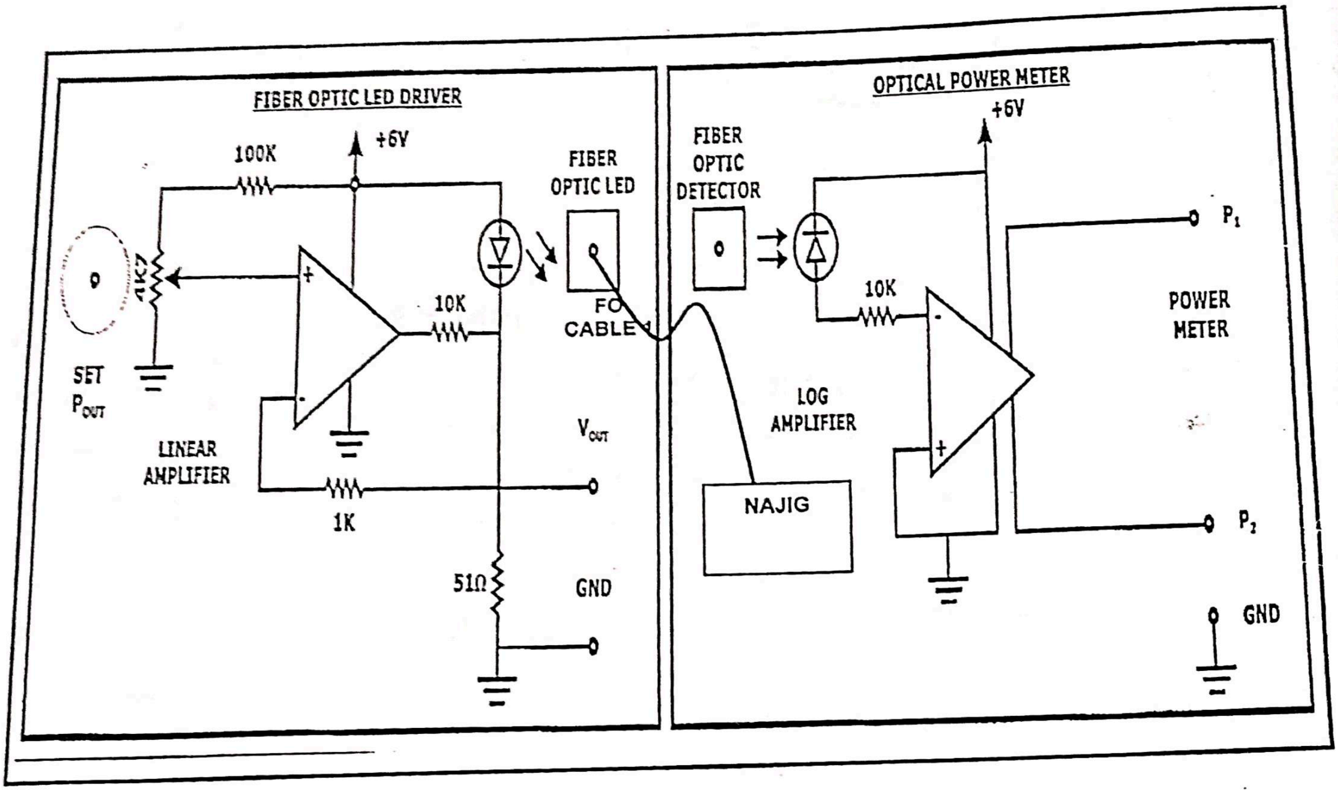
DISCUSSION:

The numerical aperture as recorded in the manufacturer's data sheet is 0.5 typically the value measured here is 0.437. The lower reading recorded is mainly due to the FIBER being under filled. The acceptance angle is given by $2\theta_{max}$. The value of 52 degrees recorded in this is close to the range of 55-60 degrees. The lower reading is again due to the FIBER being under filled.

WIRING DIAGRAM

SECTION II:

EXPERIMENT- 1

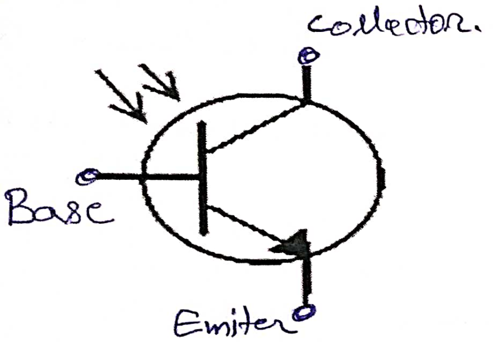


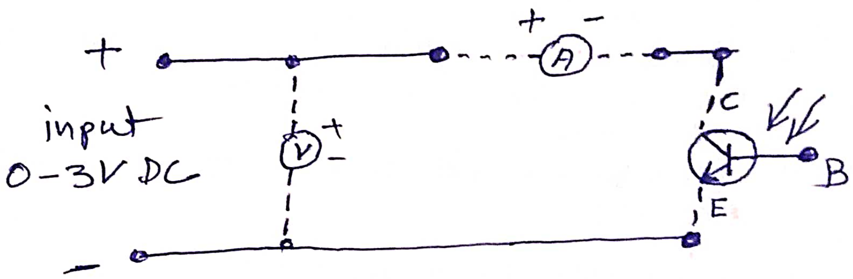
Experiment No. - 03

Aim: - **Study the characteristics of opto electronic devices, Photo transistor and Photo diode.**

Apparatus: - one DC regulated power supply of 0-3 volts, photo transistor (red terminal for collector and black terminal for emitter), voltmeter 0-3 volt DC, DC miliammiter, and one lamp with stand.

Theory: - figure 1. Shows the standard symbol of a phototransistor witch can be regarded as a conventional transistor housed in a case that enable its semiconductor functions to be exposed to external light. The device is normally used with it, base open circuit. The collector junction of the transistor is effectively reverse biased and thus acts as a photodiode the photo generated current of the base-collector junction feed directly in to the base of the diode and normal current amplifying transistor action causes the output current to appear(greatly amplified form)as collector current.in practice the collector and emitter current of the transistor are virtually identical and since base is open circuit, the device is not subjected to significant negative feedback. The sensitivity of a phototransistor is typically one hundred times greater than that of a photodiode, but its useful maximum operating frequency (a few hundred kilo hertz) is proportionally lower than that of a photodiode (ten of megahertz). A phototransistor can be converted in to a photo diode by using only its base and collector terminal and ignore the emitter.





Phototransistor

a transistor, usually bipolar, in which minority carriers are injected on the basis of an internal photoelectric effect. Phototransistors are used to convert light signals into amplified electric signals.

A phototransistor consists of a singlecrystal Ge or Si semiconductor wafer in which three regionsare pro duced by means of special technological processes. As in a conventional transistor, theregions are called the emitter, collector, and base; as a rule, the base has no lead. The crystal isplaced in a housing with a transparent window. A phototransistor is connected to an external circuit in the same way as a bipolar transistor with a common-emitter connection and a zero base current.When light is incident on the base or collector, charge-carrier pairs (electrons and holes) aregenerated in that region; the carrier pairs are separated by the electr ic field in the collector junction.As a result, the carriers accumulate in the base region, causing a reductio n of the potential barrier inthe emitter junction and an increase, or amplification, of the current across th e phototransistor incomparison with the current that is due only to the migration of carriers generated dir ectly by theaction of the light.

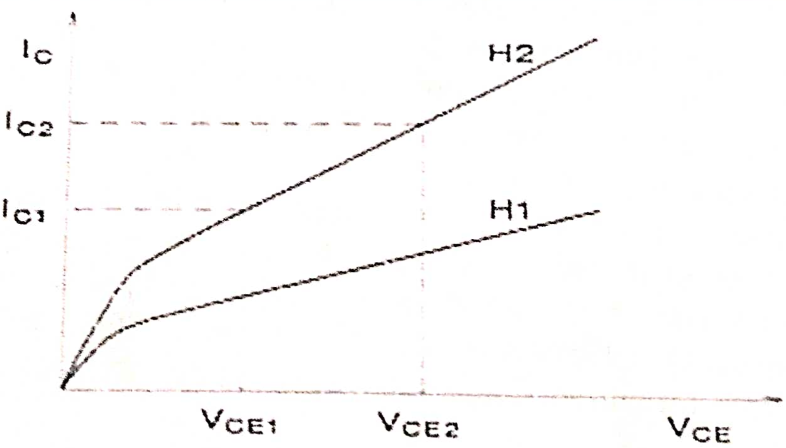
As with other photoelectric devices, such as photocells and photodiodes, the main parameters andcharacteristics of phototransistors are the luminous sensitivity, spectral response, and timeconstant. The luminous sensitivity is the ratio of the photoelectric current to the incident luminousflux. For the best specimens of phototransistors—for example, diffused planar devices the luminous sensitivity may be as high as 10 amperes per lumen. The spectral response, which is thesensitivity to monochromatic radiation as a function of wavelength, defines the long-wavelength limitfor the use of a particular phototransistor; this limit, which depends primarily on the width of theforbidden band of the semiconductor material, is 1.7 micrometers for germanium and 1.1micrometers for silicon. The time constant characterizes the inertia of a phototransistor and does notexceed several hundred microseconds. In addition, a phototransistor is characterized by thephotoelectric gain, which may be as high as 10^2–10^3.

Procedure:-

1. Connect the output of DC power supply (0-3 V DC) to the input of the photo transistor circuit. Also connect volt meter, current meter and photo transistor in the circuit through patchcords shown by circuit diagram.
2. Place the lamp holder and photo transistor on a graduated wooden stand opposite to each other. Connect the lamp to AC mains and focus the light on photo transistor.
3. Switch ON the instrument (power supply Unit) using ON/OFF toggle switch provide on the front panel.
4. Now increase the power supply voltage in small step and every time note down the voltage and current in table no. 1.
5. Plot a graph between voltage and current by taking voltage along X axis & current along Y axis.
6. Repeat the same procedure for different distances between photo transistor and lamp wen circuit is reverse bias.
7. Plot a graph between distance and current by taking distance along X axis & current along Y axis.

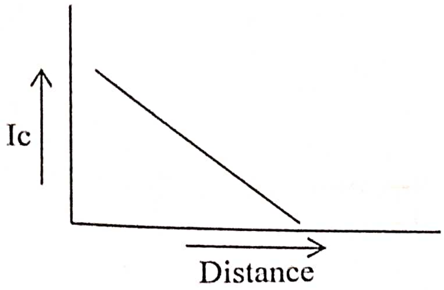
Observation table 1 (If circuit is forward bias).

s.no.	Collector voltage (Vc)	Collector current (Ic)
1		
2		
3		
4		
5		



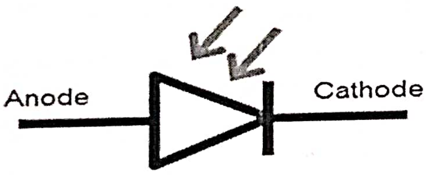
Observation table 2 (If circuit is reverse bias voltage constant).

s.no.	Distance(d) or intensity of light	Collector current (Ic)
1		
2		
3		
4		
5		

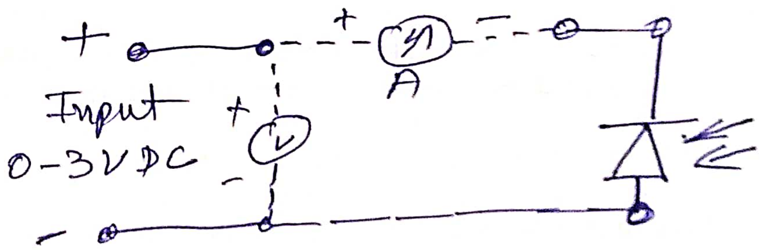


Photodiode:-

The semiconductor photodiode is a light detector device which detects presence of light. It is used to convert optical power into electrical current.PN junction Photo diode have P type and N type semiconductor forms junction. Thin P type layer is deposited on N type substrate. P-N junction has a space charge region at the interface of the P and N type material. Light enters through P-layer as shown in the following figure. This diode has relatively thin depletion region around the junction. It is reverse biased to increase width of the depletion region. Photons of light entering in P-layer ionize electron-hole pair. Photon generates electron-hole pair in the depletion region that moves rapidly with the drift velocity by the electric field. Responsivity is important technical term related to the photodiode. It is ratio of photocurrent to incident optical power. Responsivity of the photodiode is proportional to width of the junction. Photo diode is used in fiber optic communication at receiver side. It detects incoming light from the fiber end and converts it into electrical signal. It can be also used in remote Control receiver.

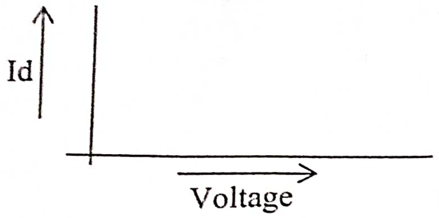


Photodiode symbol



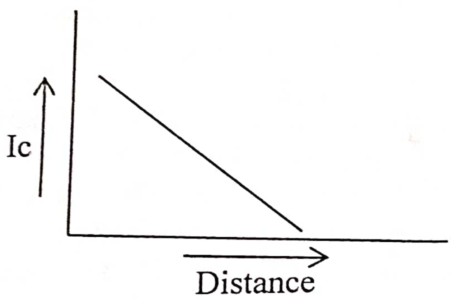
Observation table 1 (If circuit is forward bias).

s.no.	voltage (V)	Collector current (Id)
1		
2		
3		
4		
5		



Observation table 2 (If circuit is reverse bias voltage constant).

s.no.	Distance(d) or intensity of light	Current (Id)
1		
2		
3		
4		
5		



Result:- 1. The forward resistance of phototransistor is ……..and found the reverse current I (decreases when the intensity of light decreases, distance between lamp and transistor increases.

2. The forward resistance of photodiode is ……..and found the reverse current Idr (decreases when the intensity of light decreases, distance between lamp and transistor increases.

Precautions:-

1. **Firstly read about complete experiment then perform.**
2. **Connect circuit properly according to diagram.**
3. **Check connecting wires before use.**
4. **Connect current meter in series only.**

PHOTOCONDUCTIVITY

INDOSAW

Instruction Manual

Photoconductivity

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INDOSAW

Objectives

(1) To plot the current-voltage characteristics of a CdS photo-resistor at constant irradiance.

(2) To measure the photo-current as a function of the irradiance at a constant voltage.

Apparatus INDOSAW SK007

Introduction

When light radiations fall on the insulating crystal, an increase in electrical conductivity of the crystal takes place. This phenomenon is called photoconductivity. Gudden and Pohl did a lot of research work on photoconductivity. They found that:

(a) For a given material there was a similar dependence of light absorption and the extinction of photoconductivity by light on the wavelength of light.

(b) The presence of impurities extended the region of photosensitivity to longer wavelengths.

(c) Some impurities when incorporated could reduce photosensitivity of the material. Direct effect of illumination is to increase the number of mobile charge carriers in the crystal.

Theory

When the energy of the incident photon exceeds the energy gap E_g, free electron-hole pairs are produced in the crystal due to the absorption of the incident photons. The electrons and the holes serve as the carriers of the electrical conductivity. The electrons are in the conduction band and the holes in the valence band of the crystal. Therefore, photoconductivity arises due to the reason that the incident photons excite the electrons from the valence band into the conduction band where they become mobile and creation of holes in the valence band where they are also mobile.

It may be pointed out that photo-conduction is not an intrinsic phenomenon. The impurities and imperfections in the crystals also contribute to the photoconductivity. If donor /acceptor impurities are present, then even the photons having energy below the threshold for the production of electron-hole pairs may be able to produce mobile electrons or holes.

The role of imperfections is quite important in understanding the phenomenon of photoconductivity. Due to imperfections, discrete energy levels are introduced in the forbidden energy gap. These are called *traps*.

Thus, photoconductivity is a process in which electrons (or holes) are freed from one or other type of bound state by photons, spend some time in the conduction band (or valence band) in which they act current carriers and are finally recaptured by the traps. As soon as the incident radiation is removed, photoconductivity disappears because the holes and electrons recombine with each other.

Variation of photoconductivity with illumination

Let us suppose that electron-hole pairs are produced uniformly throughout the volume of the crystal by irradiation with an external light source. Recombination occurs by direct combination of electrons with holes. It may be assumed that electrons leaving the crystal at one end are replaced by electrons flowing in from the opposite electrode. The mobility of holes may be neglected in comparison with the mobility of the electrons.

Photoconductivity may be written as

$$\sigma = n_0 e \mu \quad (1)$$

where, μ is the electron mobility and n_0 is the electron concentration in the steady state. At a given voltage, the photo-current varies with light intensity as $L^{1/n}$, where L is the number of photons absorbed per unit volume of the specimen per unit time. The exponent observed may be usually between ½ and 1, with some crystals having higher exponent. In case of CdS crystal, the exponent varies between 0.92 at low level and 0.58 at high level of illumination. The response time is given by

$$t_0 = n_0 / L$$

From equation (1) we get

$$n_0 = \sigma / e \mu$$

$$t_0 = \sigma / e \mu L \quad (2)$$

Response time is the time during which carrier concentration should drop to $0.5\,n_0$.
Response time should therefore be directly proportional to the photoconductivity at a given illumination level L. Sensitive photo-conductors should have long response time.

Effect of traps

A trap is an impurity atom or other imperfection in the crystal capable of capturing an electron or hole. The captured carrier may be re-emitted at a subsequent time and may move to another trap. There are two types of traps:

(i) One type helps in recombination of holes & electrons and thus to restore thermal equilibrium. These traps are called as *recombination centres*. Recombination takes place at much higher rate in the presence of traps.

(ii) Second type of traps affect mainly the freedom of motion of charge carriers of one sign or the other. It is observed therefore, that the presence of traps reduces the conductivity and also reduces the response time.

Space charge effects

In photo-conductors, space charges arise when the illumination is not uniform throughout the crystal or when the electrodes cannot supply charge carriers freely in the crystal. The photo-currents may be reduced effectively and ultimately stop flowing when the electric field of the surface charges just cancels the field applied by the electrodes.

Procedure

(1) Mount the lamp housing (H), adjustable slit self-centering (A), polarizer (P_1), analyzer (P_2), lens (L_1) and photo-resistor (R) on the optical bench as shown in fig 1.

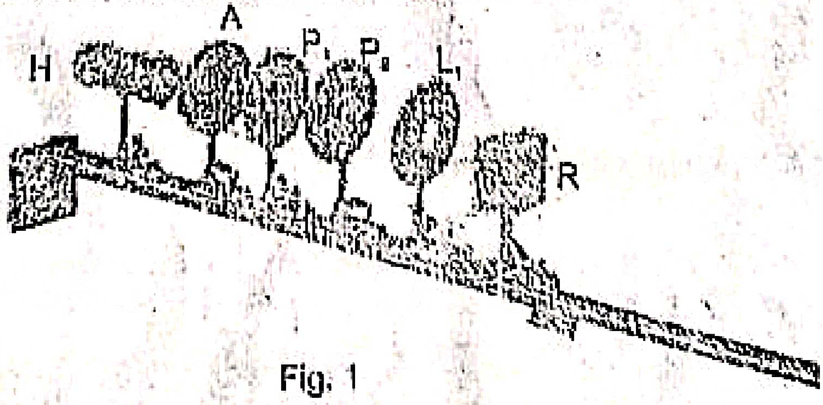


Fig. 1

(2) Connect the leads of the lamp housing to the power supply (0-12 V AC/DC, 5 Amp.) and apply 10 V AC to the lamp.

(3) Adjust the heights of the lamp housing, adjustable slit self-centering, polarizer, analyzer, lens and photo-resistor such that all of them lie on same optical axis.

(4) Make the connections to the photo-resistor and multimeter as shown in fig.2

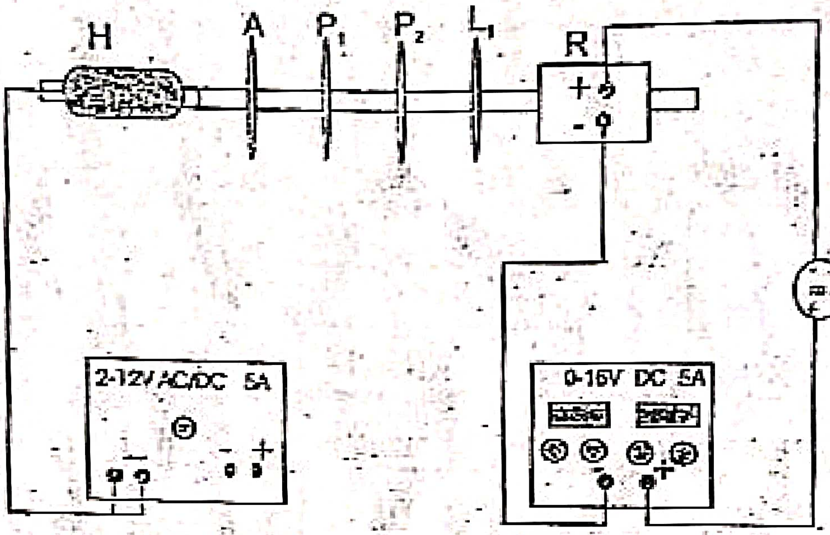


Fig. 2

(5) Initially set the polarizer and analyzer at 0° mark.

(6) Adjust the lamp, lens and photo-resistor so that a homogeneous ray of light illuminates the photo-resistor.

(7) Set the voltage of DC power supply (0-16 VDC, 5 Amp.) to 12 V.

(8) Adjust the width of the self centering adjustable slit so that a current of about 9 mA flows through the photo-resistor. Keep the width of the slit fixed for the experiment.

Note: *When the illumination is changed, the response of the photo-resistor is slow. It takes some time until the new value of the resistance is reached. Before noting the values, wait until a stationary state is reached.*

(a) Measuring the photo-current I_A as a function of the voltage U at a constant irradiance

(i) Set the analyzer at 0° mark provided on the analyzer.

(ii) Interrupt the path of the ray of light and determine the photo-current I_0 due to residual lightness.

(iii) Starting from 16 V, reduce the voltage U to 0 V in steps of 2 V. Measure the photo-current I_A each time and record it.

(iv) Repeat the series of measurements with analyzer at 30°, 60° and 90°.

(b) Measuring the photo-current I_{ph} as a function of the irradiance at a constant voltage U

(i) Set the voltage U to 16 V, interrupt the path of the ray of light and measure the photo-current I_p due to residual lightness.

(ii) In order to vary the irradiance, increase the angle between the polarization planes of the polarizers in steps of 10° from 0° to 90°. Measure the photo-current I_{ph} each time and record it.

(iii) Repeat the series of measurements at U = 8 V and U = 1 V.

Note: The photo-resistor is influenced even by slight residual lightness in the experiment room. The experiment must be performed in a dark room.

Observations

1) Measuring photo current I_{ph} as a function of Voltage U at a constant irradiance ϕ:

U (V)	I_{ph} at 0° (mA)	I_{ph} at 30° (mA)	I_{ph} at 60° (mA)	I_{ph} at 90° (mA)
16	9.75	5.63	3.08	0.93
14	8.43	4.92	2.70	0.81
12	7.27	4.21	2.29	0.69
10	5.82	3.47	1.89	0.57
8	4.57	2.74	1.50	0.45
6	3.24	2.03	1.10	0.33
4	2.00	1.35	0.74	0.22
2	0.77	0.69	0.37	0.11

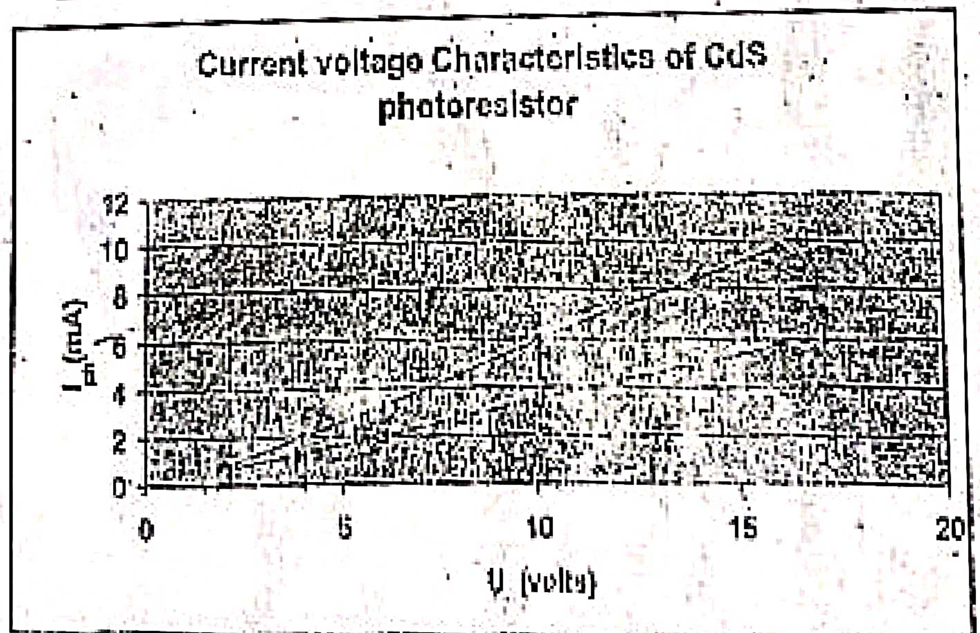
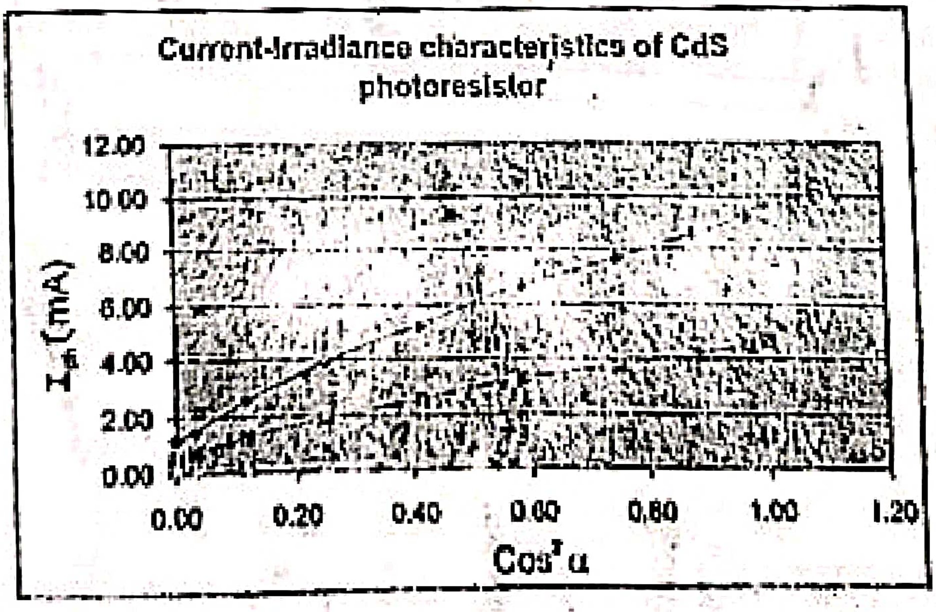


Fig. 3

2) Measuring photo current I_{ph} as a function of irradiance ϕ at a constant voltage U:

α	$Cos^2\alpha$	I_{ph} at 16V (mA)	I_{ph} at 8V (mA)	I_{ph} at 1V (mA)
0°	1.00	9.73	4.68	0.57
10°	0.97	9.19	4.47	0.54
20°	0.88	8.61	4.19	0.51
30°	0.75	7.70	3.75	0.49
40°	0.59	6.68	3.23	0.39
50°	0.41	5.25	2.55	0.33
60°	0.25	3.92	1.89	0.24
70°	0.12	2.57	1.23	0.15
80°	0.03	1.50	0.71	0.09
90°	0.00	1.11	0.53	0.06



Result

The CdS photo-resistor behaves like an ohmic resistance that depends upon the irradiance.