APPLIED PHYSICS

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TOPIC

Demonstrate and analyze of:

- **Photo diode**
- **LED**
- **Laser diode**

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Topic: Photodiode

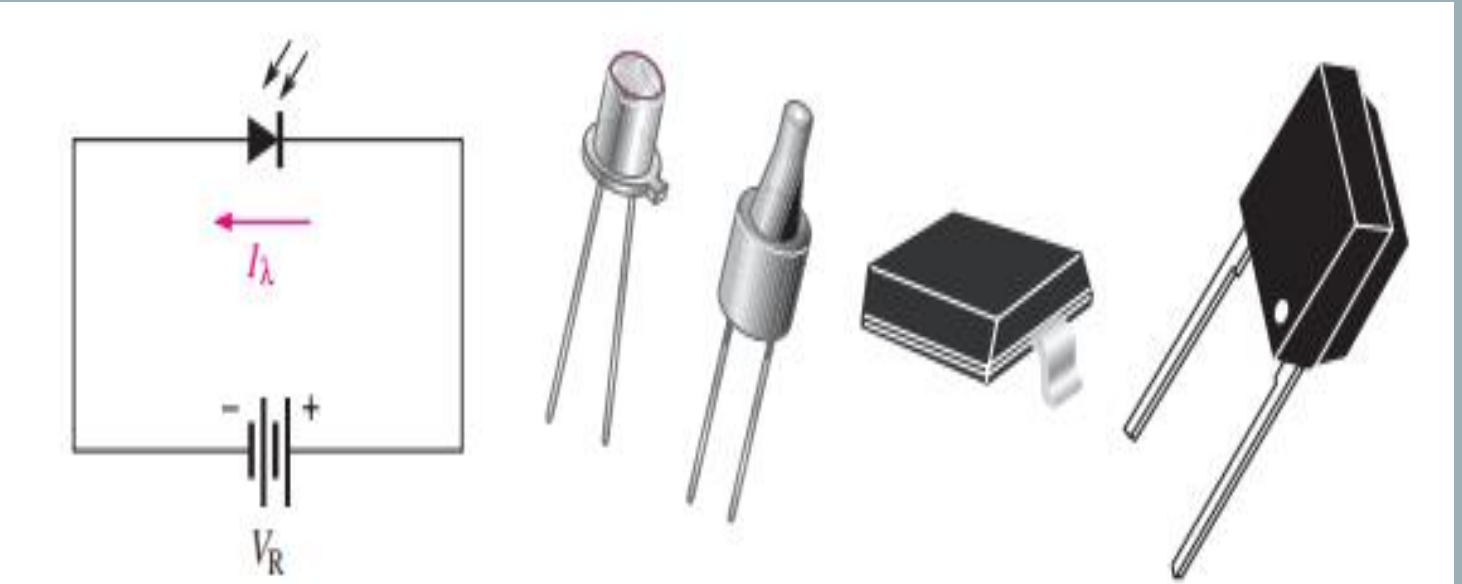
What is Photodiode?

A photodiode is a PN-junction diode that consumes light energy to produce an electric current. They are also called a photo-detector, a light detector, and a photo-sensor. Typical photodiode materials are Silicon, Germanium and Indium gallium arsenide.

Photodiodes are specially designed to operate in reverse bias condition. Reverse bias means that the p-side of the photodiode is connected to the negative terminal of the battery and n-side is connected to the positive terminal of the battery.

Photodiode is very sensitive to light so when light or photons falls on the photodiode it easily converts light into electric current. Solar cell is also known as large area photodiode because it converts solar energy or light energy into electric energy. However, solar cell works only at bright light.

The **photodiode** is a device that operates in reverse bias, as shown in Figure (a),where is the reverse light current. The photodiode has a small transparent window that allows light to strike the *pn* junction. Some typical photodiodes are shown in Figure (b).

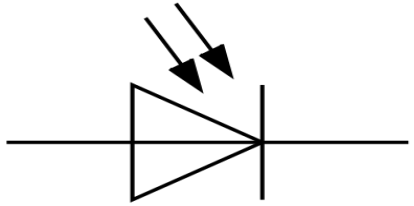


(a) Reverse-bias operation using standard symbol

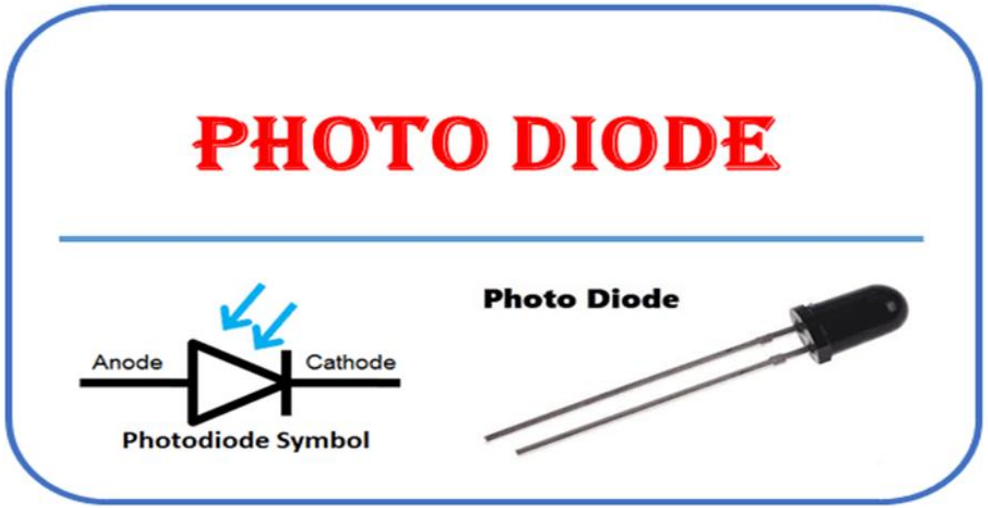
(b) Typical devices

Symbol of Photodiode

The following image shows the symbol of the photodiode:



The symbol of the photodiode is similar to that of an LED, but here the arrow points inwards.



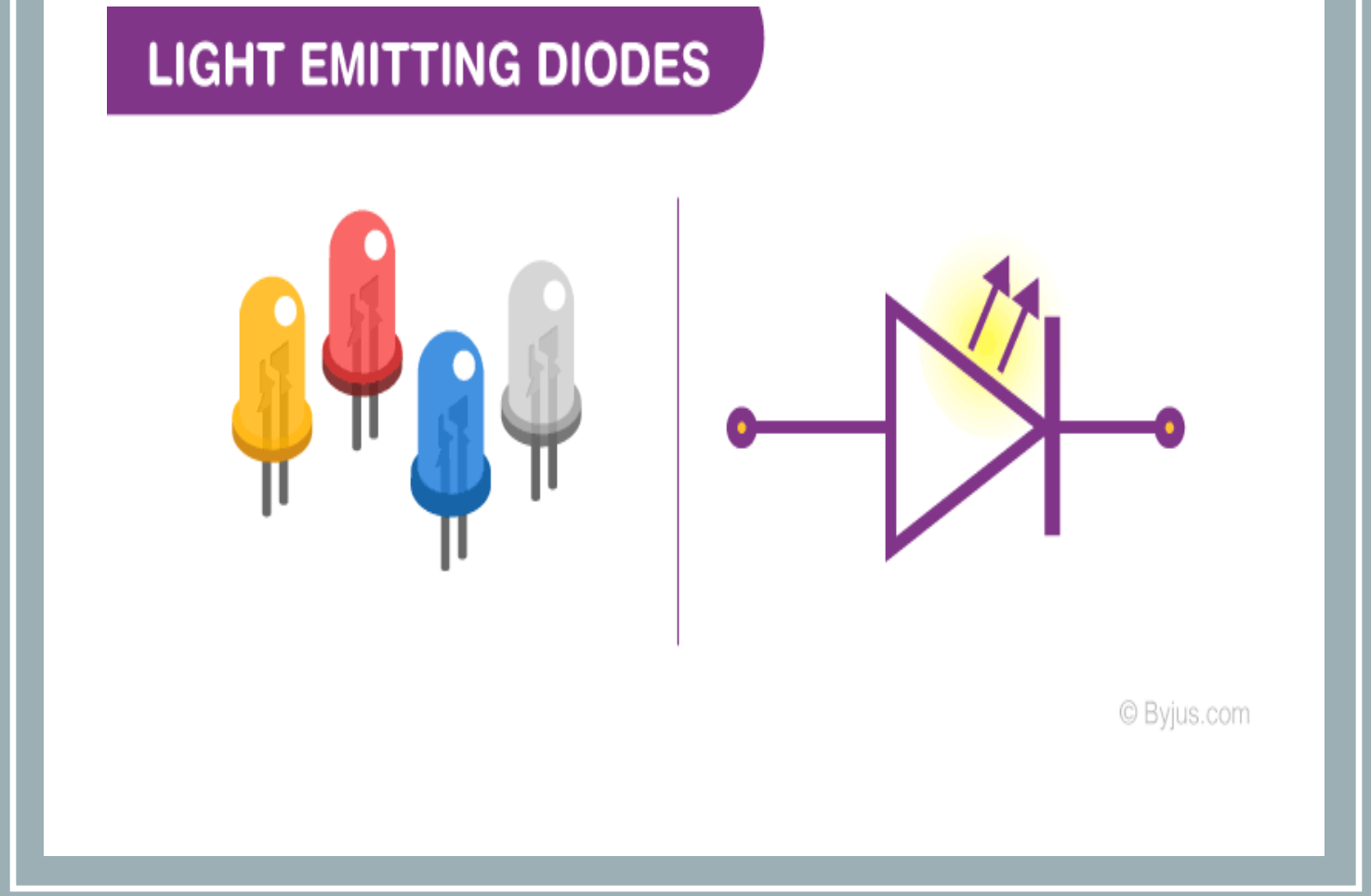
How does Photodiode work?

- It has a P and N junction and is connected in reverse bias that results in a very wide depletion region at the PN Junction. In P-type the majority carriers are holes and n-type majority carriers are electrons. When we connect the photodiode in reverse bias and if there is no illumination or light on photodiode in that condition we get a very small amount of current in microampere we called that current as dark current.
- When a photon having energy greater than the bandgap energy strikes on diode covalent bond breaks and new electrons and hole pairs are generated. This makes a couple of electrons and holes called inner photoelectric effect and the holes move towards the anode and electrons move toward cathode this results in photocurrent. The total current through the diode is the sum of dark current and photocurrent. To maximize the sensitivity of photodiode we need to minimize the dark current.

Applications of Photodiode

- Photodiodes are used in simple day-to-day applications. The reason for their prominent use is their linear response of photodiode to light illumination.
- Photodiodes with the help of optocouplers provide electric isolation. When two isolated circuits are illuminated by light, optocouplers are used to couple the circuit optically. Optocouplers are faster compared to conventional devices.
- Photodiodes are used in safety electronics such as fire and smoke detectors.
- Photodiodes are used in numerous medical applications. They are used in instruments that analyze samples, detectors for computed tomography and also used in blood gas monitors.
- Photodiodes are used in solar cell panels.
- Photodiodes are used in logic circuits.
- Photodiodes are used in the detection circuits.
- Photodiodes are used in character recognition circuits.
- Photodiodes are used for the exact measurement of the intensity of light in science and industry.
- Photodiodes are faster and more complex than normal PN junction diodes and hence are frequently used for lighting regulation and optical communication.

TOPIC: LED

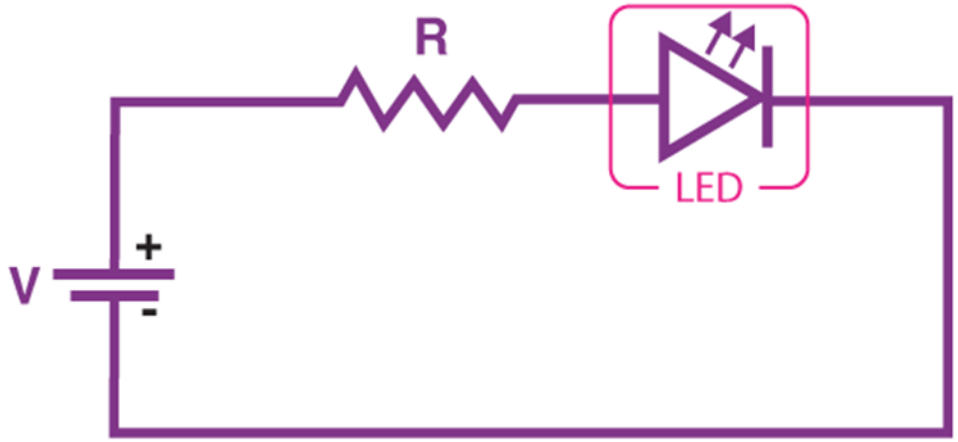


What is LED?

A light-emitting diode (LED) is a semiconductor device that emits light when an electric current flows through it. When current passes through an LED, the electrons recombine with holes emitting light in the process. LEDs allow the current to flow in the forward direction and blocks the current in the reverse direction.

Light-emitting diodes are heavily doped p-n junctions. Based on the semiconductor material used and the amount of doping, an LED will emit colored light at a particular spectral wavelength when forward biased.

SIMPLE LED CIRCUIT



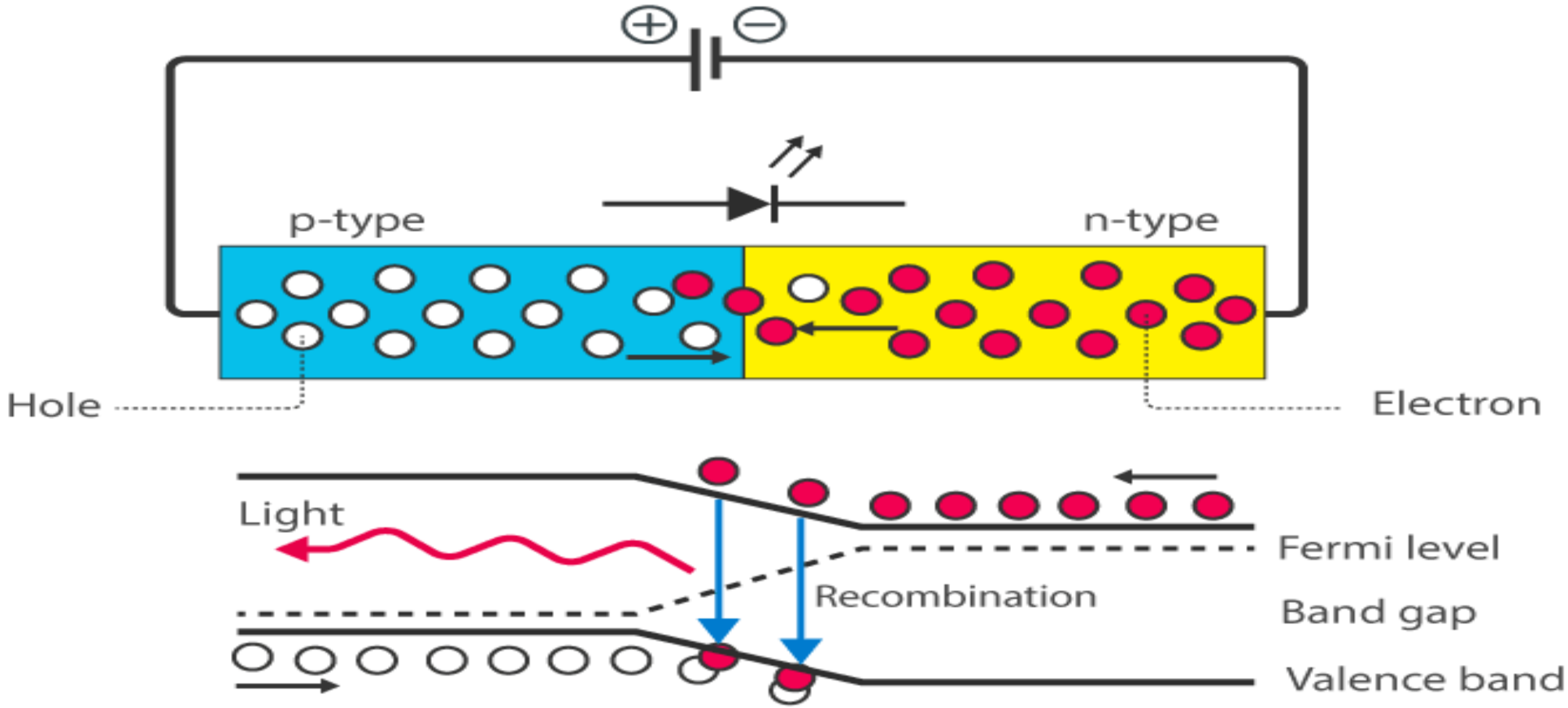
LED Circuit

How does an LED work?

When the diode is forward biased, the minority electrons are sent from p → n while the minority holes are sent from n → p. At the junction boundary, the concentration of minority carriers increases. The excess minority carriers at the junction recombine with the majority charges carriers.

The energy is released in the form of photons on recombination. In standard diodes, the energy is released in the form of heat. But in light-emitting diodes, the energy is released in the form of photons. We call this phenomenon electroluminescence. Electroluminescence is an optical phenomenon, and electrical phenomenon where a material emits light in response to an electric current passed through it. As the forward voltage increases, the intensity of the light increases and reaches a maximum.

WORKING PRINCIPLE OF LED



Types and uses of LEDs

Types of LED

Below is the list of different types of LED that are designed using semiconductors:

- Miniature LEDs
- High-Power LEDs
- Flash LED
- Bi and Tri-Colours
- Red Green Blue LEDs
- Alphanumeric LED
- Lighting LED

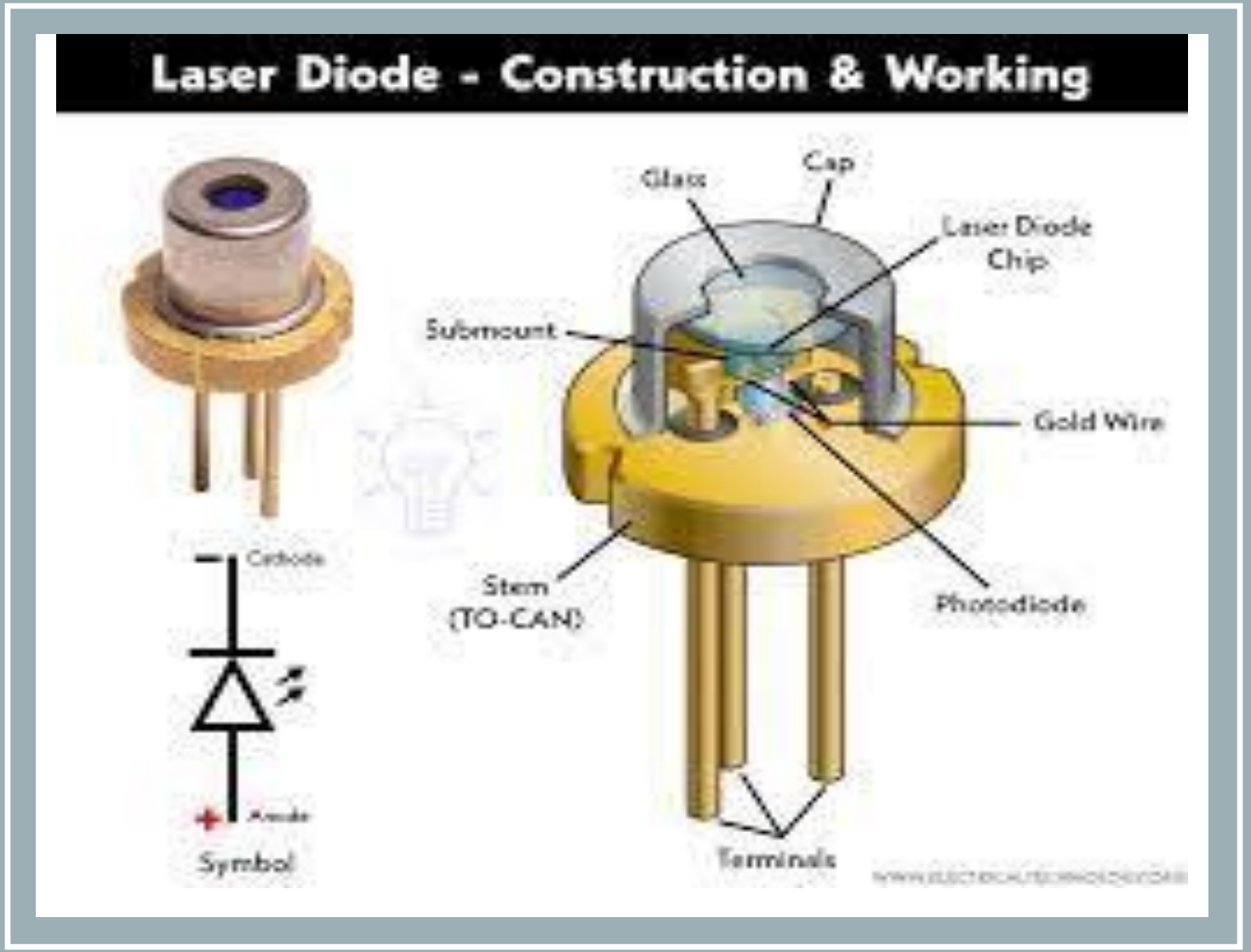
Uses of LED

LEDs find applications in various fields, including optical communication, alarm and security systems, remote-controlled operations, robotics, etc. It finds usage in many areas because of its long-lasting capability, low power requirements, swift response time, and fast switching capabilities.

Below are a few standards LED uses:

- Used for TV back-lighting
- Used in displays
- Used in Automotive
- LEDs used in the dimming of lights

TOPIC: LASER DIODE

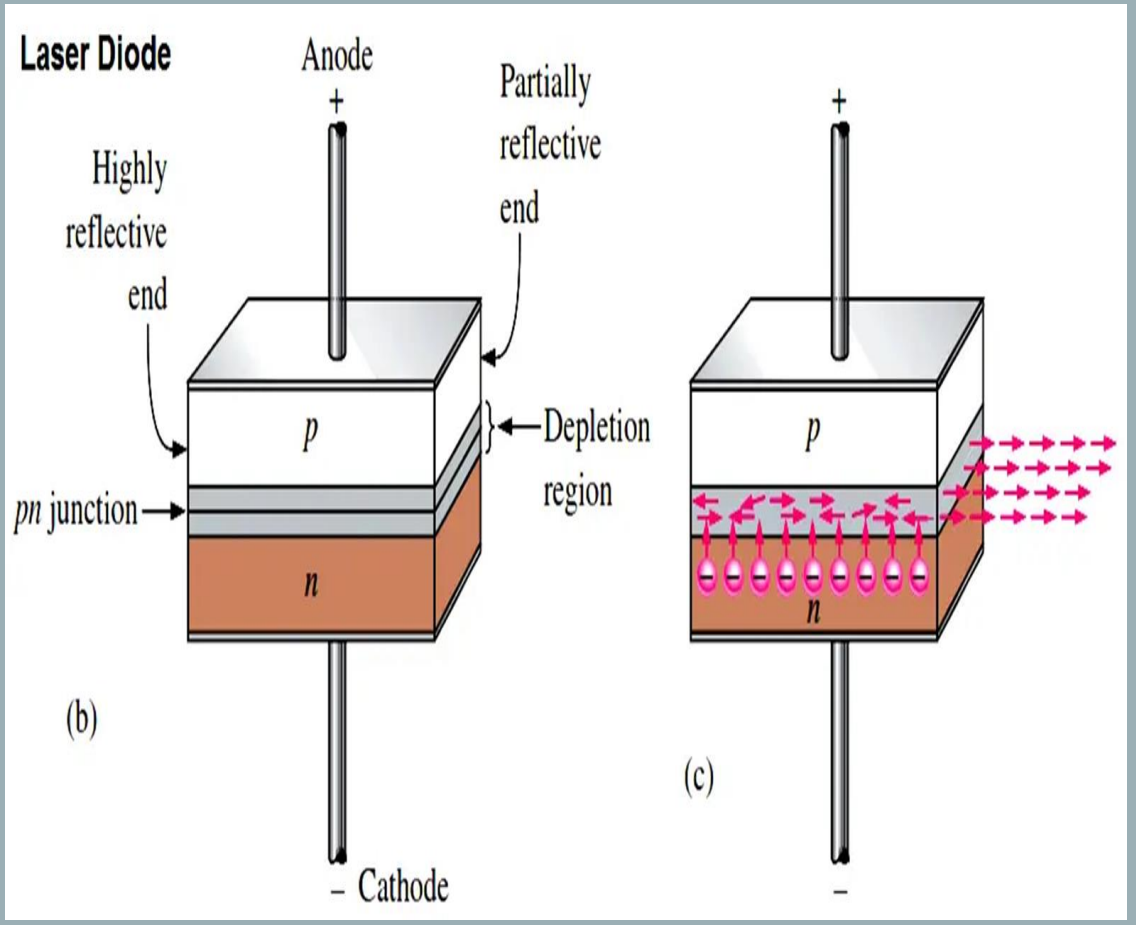


What Is a Laser Diode?

- A laser diode is a semiconductor that uses a p-n junction for producing coherent radiation with the same frequency and phase, which is either in the visible or infrared spectrum. It is also called an injection laser diode and the technology is similar to that found in LED.
- The term laser stands for light amplification by stimulated emission of radiation. Laser light is monochromatic, which means that it consists of a single color and not a mixture of colors.
- Laser light is also called coherent light, a single wavelength, as compared to incoherent light, which consists of a wide band of wavelengths. The laser diode normally emits coherent light, whereas the LED emits incoherent light.

Basic laser diode construction.

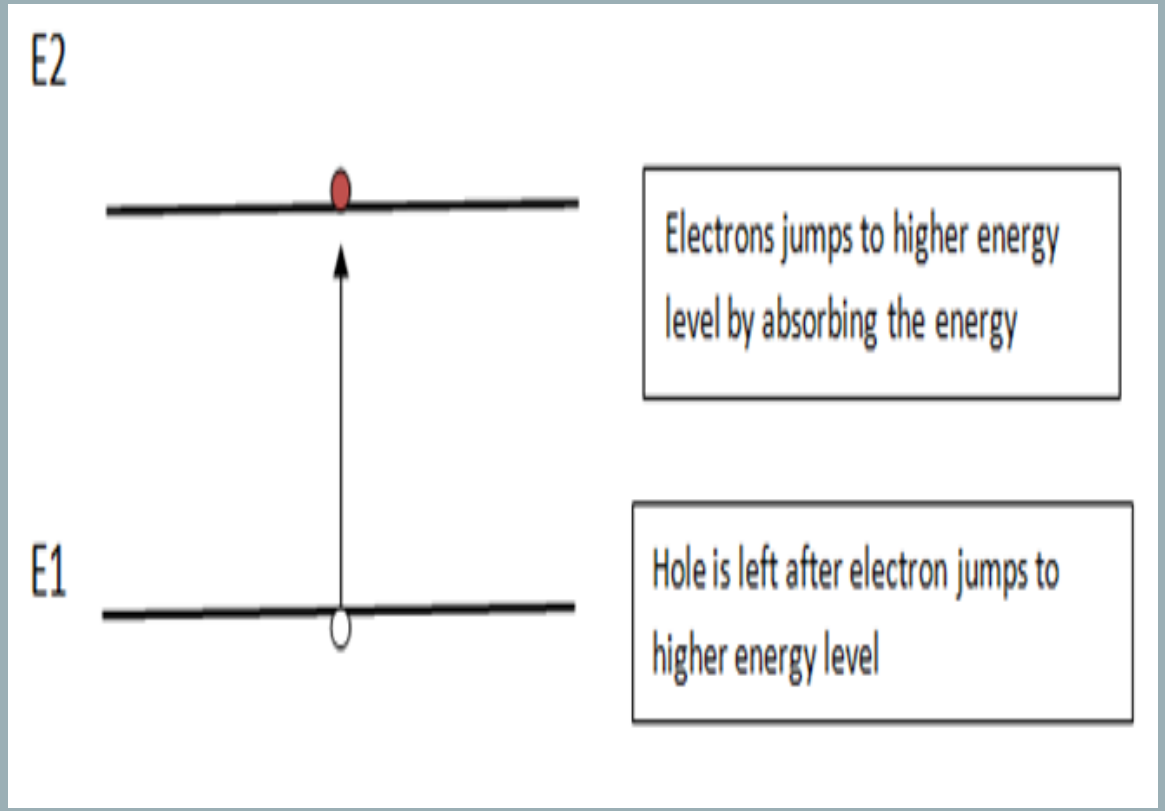
- The construction mainly consists of metal contact, P type material N type material, intrinsic active region. The P type and N type material is formed by doping aluminum or silicon with Gallium arsenide.
- The active region is made up of undoped gallium arsenide. This increases the active region, so that holes and electrons combining area increases. In the mirror polished surface more holes and electrons get reflected and combine with each other which results in more radiation.



Working of Laser diode:

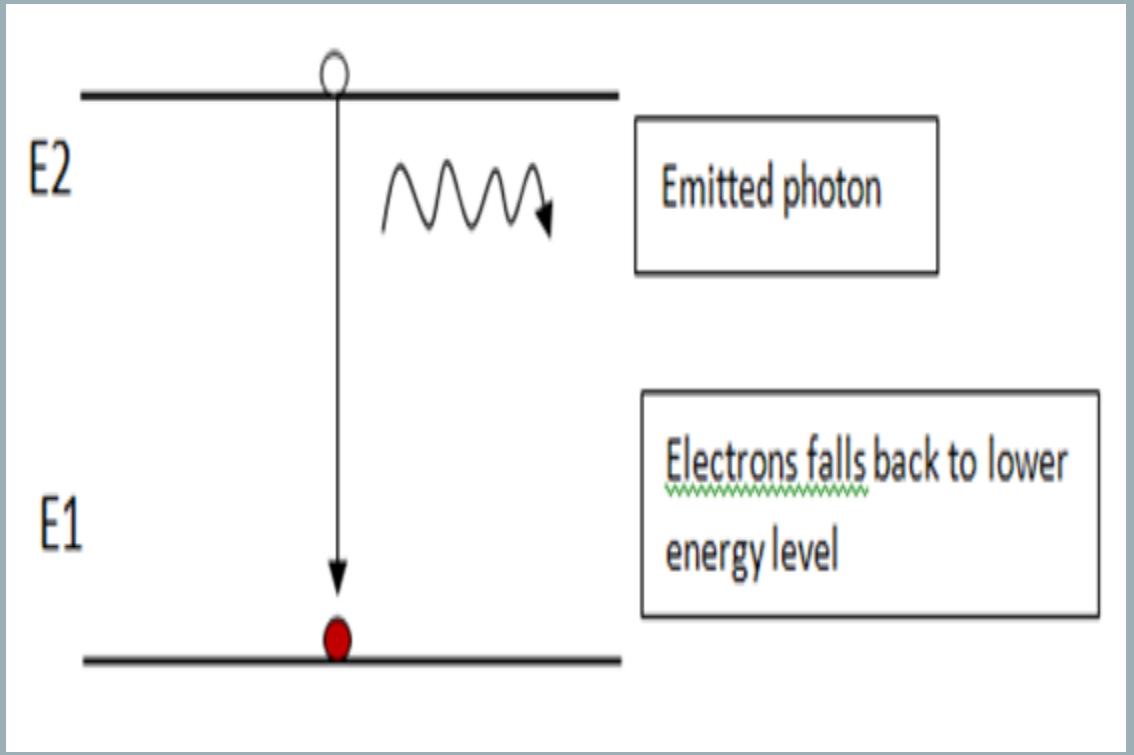
Energy Absorption:

- The Laser diode consists of both holes and electrons . when the external voltage is applied at the PN Junction the electrons absorbs some energy and get excited to higher energy level from lower energy level.
- The electrons remains excited for few Nano seconds before they combine with holes. This time is called recombination time.



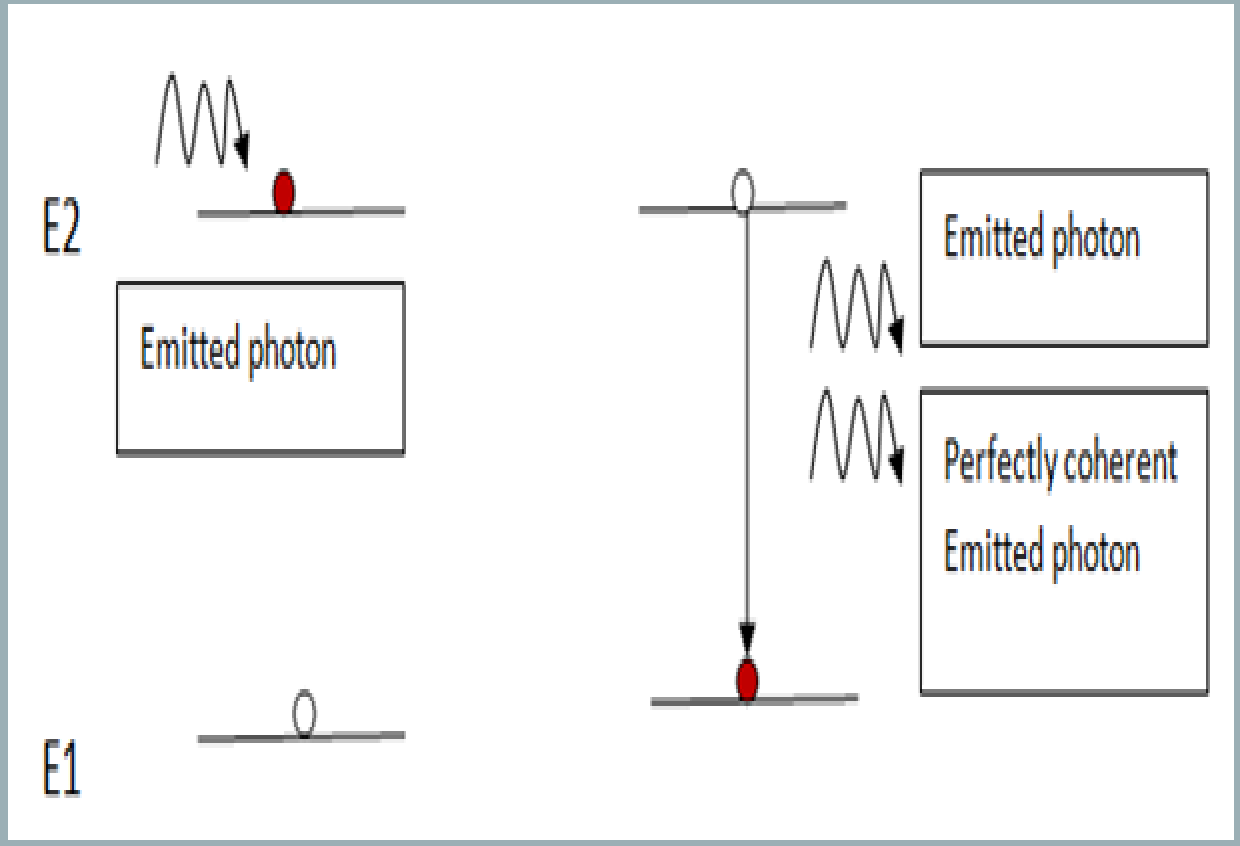
Spontaneous emission:

- After the electrons get excited and recombine with the holes they again travel to lower energy level. While travelling to lower energy level they emit photon in the form of electromagnetic wave and the energy of the photon is the difference between the higher energy level and lower energy level.



Stimulated emission:

- As we need more coherent photons, reflecting mirrors are used at the either side of the PN Junction diode. So the photons gets trapped inside the junction and they stimulate the excited electrons to recombine with the holes before the recombination time and thus more photons are emitted .
- when the photon concentration reaches the threshold they escape through the partially reflecting mirror . This results in bright monochromatic coherent light.



Characteristics of Laser Diode

The laser diode is characterized as follows:

Monochromaticity: Laser light is characterized by its high degree of monochromaticity, meaning it consists of a single color or wavelength. This is in contrast to conventional light sources, which often emit different spectrum of colors.

Coherence: Laser light is coherent, meaning that the electromagnetic waves emitted from a laser have a consistent phase relationship. This coherence allows laser light to be focused to a tight spot and used for applications such as holography.

Directionality: Laser light is highly directional, meaning it can be focused into a narrow beam over long distances without significant spreading. This property is essential for applications like laser pointers and laser communication systems.

Applications of Laser Diode

The following are the applications of laser diodes:

•**Consumer electronics:** This includes laser printers, CDs and DVD players, and fiber optic communication.

•**Industrial applications:** When it comes to industrial applications, laser diode is preferred as it is a source of a high-intensity laser beam and used for cutting, drilling, welding, etc.

•**Medical applications:** Laser diodes are used for the elimination of unwanted tissues and tumors and also in dental medication.

•**Scientific instrumentation:** Instruments like spectrometers, range finders, contact-less measurements can be done with the help of laser diodes.

•**The laser diode in telecom:** Laser diodes with 1.3 μm and 1.55 μm bands are used as the main source of light in telecom and as the band changes laser diodes find application in optical amplification.

Advantages of Laser Diode

The following are the advantages of laser diode:

•When a laser diode is compared with other light-emitting devices, the operational power is less in the laser diode.

•The handling of these diodes is easy as they are small.

•The light generated by these diodes is of high efficiency.

Disadvantages of Laser Diode

The following are the disadvantages of laser diode:

•These diodes are expensive when compared to other light-emitting devices.

•The light generated by these diodes adversely affects the eyes.


Thank you!