Module:7 **Sources LED & Laser diode**

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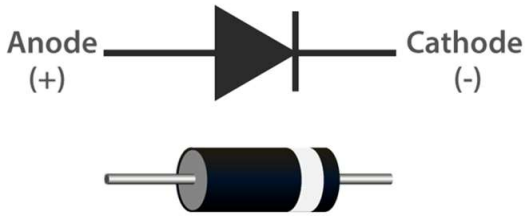
Optical source

- LED (Light emitting diode)
- Laser diode

Diode

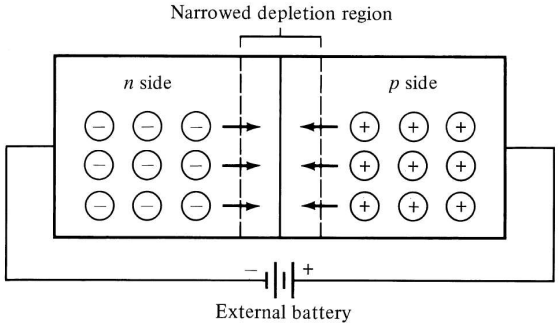


- A semiconductor diode is a p-n junction diode. It is a two-terminal device that conducts current only in one direction.
- Diodes can be made of either of the two semiconductor materials, silicon and germanium.
- When the anode voltage is more positive than the cathode voltage, the diode is said to be forward-biased and it conducts readily with a relatively low-voltage drop.
- Likewise, when the cathode voltage is more positive than the anode, the diode is said to be reverse-biased.
- The arrow in the diode symbol represents the direction of conventional current flow when the diode conducts.

Ordinary PN junction Diode working

Ordinary diode works (produce current) in forward bias condition

Forward bias condition: Positive terminal of the battery connected to p-type semiconductor and negative terminal connected to n-type semiconductor



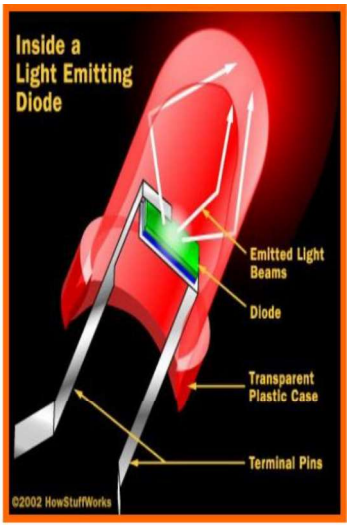
Ordinary diode is non-radiative

Do not produce light up on electron and hole transport

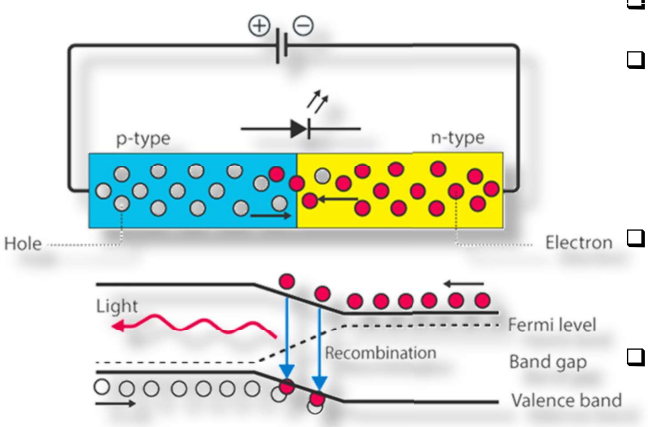
What is LED?

LED are semiconductor p-n junctions that under forward bias conditions can emit radiation by electroluminescence in the UV, visible or infrared regions of the electromagnetic spectrum. The qaunta of light energy released is approximately proportional to the band gap of the semiconductor.

- A light emitting diode (LED) is essentially a PN junction opto-semiconductor chip.
- LED's convert electrical energy into light energy.
- Emits a monochromatic (single color) light when operated in a forward biased direction.
- The quanta of light energy released is approximately proportional to the band gap energy of the semiconductor.



Working Principle of LED



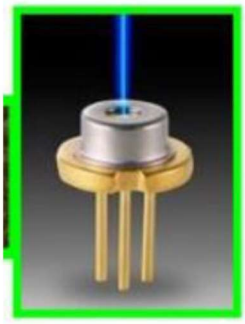
- A typical LED needs a forward biased p-n junction
- When this movement of free electron and hole takes place, there is a change in the energy level as the voltage drops from the conduction band to the valance band. There is a release of energy due to the motion of the electron.
- In standard diodes, the release of energy in the manner of heat. But in LED the release of energy in the form of photons would emit light energy.
- **Electrons and Holes recombine and produce light**
- The entire process is known as **electroluminescence**, and the diodes are known as a light-emitting diode.

LED

Advantage	Disadvantage
Smaller in size	Power output is low
Low cost	Intensity is less than laser
Long Life	Cannot travel longer distance
Different colours	Incoherent and not in phase
Operation at low voltage	Have no directionality
Very fast response (10^{-9}s)	
Easy Intensity control	
Less scattering	

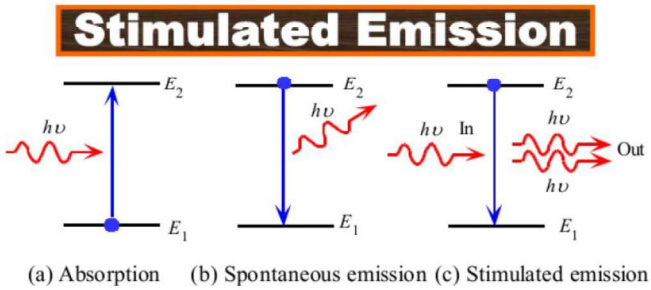
Semiconductor Diode Laser

- **A semiconductor laser is a specially fabricated pn junction device (both the p and n regions are highly doped) which emits coherent light when it is forward biased.**
- **Gallium Arsenide (GaAs) is used as a semiconductor in these lasers. It emits light in near IR region.**



Semiconductor lasers can also be made to emit light in the spectrum from UV to IR using different semiconductor materials e.g. InGaAs, AlGaAs etc.

Laser Principle

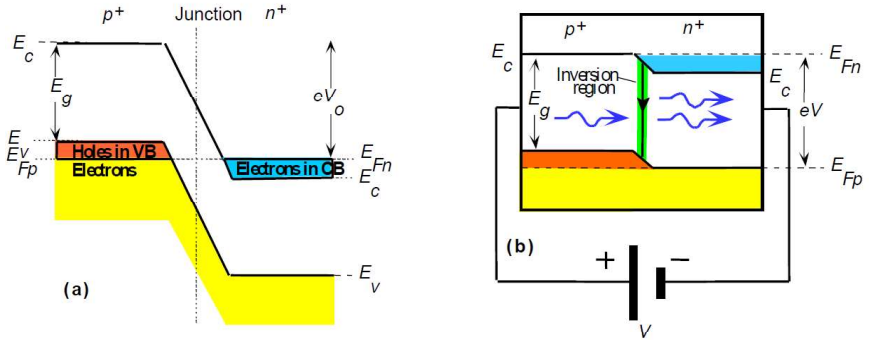


(a) Absorption (b) Spontaneous emission (c) Stimulated emission

- ❑ **To design a laser diode, the p-n junction must be <u>heavily doped</u> i.e., p and n materials must be <u>degenerately doped.</u>**
- ❑ **By degenerated doping, the Fermi level of the n-side will lie in the conduction band whereas the fermi level in the p-region will lie in the valence band.**
- ❑ **Light emission should be stimulated.**
- ❑ **Stimulated emission - an electron in a higher energy state interacts with a photon that stimulates it to return to a lower energy state, and a photon is released.**

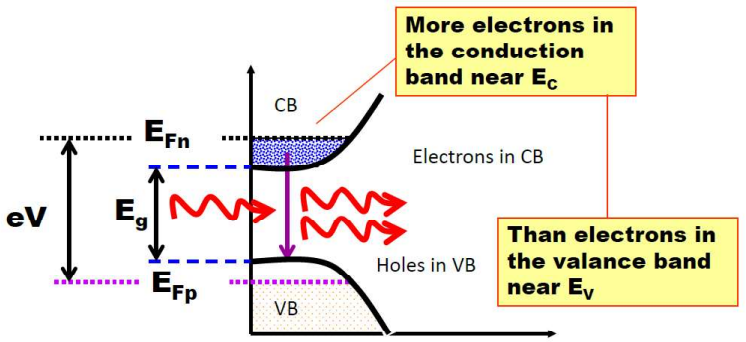
Working of Semiconductor lasers

After positive bias



- When the junction is forward biased, Electron can flow to p-region and holes can flow to n-region
- at low voltage the electron and hole recombine and cause spontaneous emission
- But when the forward voltage reaches a threshold value, the carrier concentration rises to very high value.

Population Inversion in Diode Laser



Population inversion is achieved by direct conversion method of pumping

E_{Fn}-E_{fP} = eV

eV > E_g

eV = forward bias voltage

Fwd Diode current pumping → injection pumping

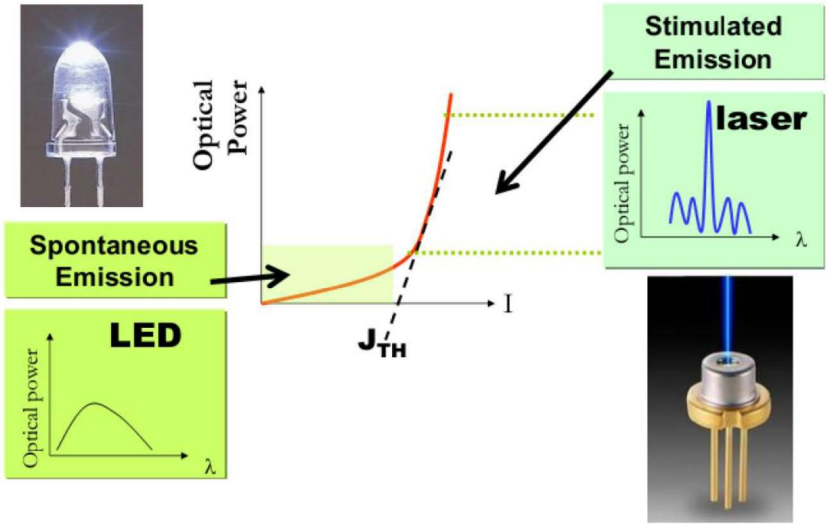
❑There is therefore a **population inversion** between energies near E_C and near E_V around the junction.

❑This only achieved when degenerately doped p-n junction is forward bias with energy > E_{gap}

Laser diode

Advantage	Disadvantage
When laser diode is compared with other light-emitting devices, the operational power is less in the laser diode	These diodes are expensive when compared to other light-emitting devices.
The handling of these diodes is easy as they are small.	The light generated by these diodes adversely affect the eyes.
The light generated by these diodes is of high efficiency	

LED vs Laser diode



Comparison of a Semiconductor Diode Laser and LED

Semiconductor Diode Laser	LED
Stimulated radiation	Spontaneous radiation
narrow line width	broad spectral
coherent	incoherent
higher output power	lower output power
a threshold device	no threshold current
strong temperature dependence	weak temperature dependence
higher coupling efficiency to a fiber	lower coupling efficiency