2.10 Types of Lasers

Lasers are classified into five major categories based on the type of active medium.

(i) Solid state laser

Example: Ruby, Nd-YAG laser

(ii) Gas Lasers

Example: CO_2, He-Ne and Ar laser

(iii) Semiconductor laser

Example: GaAs, GaAsP, GaAlAs, InP lasers

(iv) Liquid lasers

(v) Dye laser

Homojunction Semiconductor LASER (GaAs)

Characteristics

Type	- Homojunction Semiconductor laser
Active medium	- P-N junction diode
Active centre	- Recombination of electrons and holes
Pumping method	- Direct pumping
Optical Resonator	- Junction of diodes - polished
Power output	- 1 mW
Nature of output	- Pulsed or Continuous waveform
Wavelength	- $8400A^0 – 8600A^0$
Band gap	- 1.44 eV

Principle:

The electron in conduction band combines with a hole in the valence band and hence the recombination of electron and hole produces energy in the form of light. This

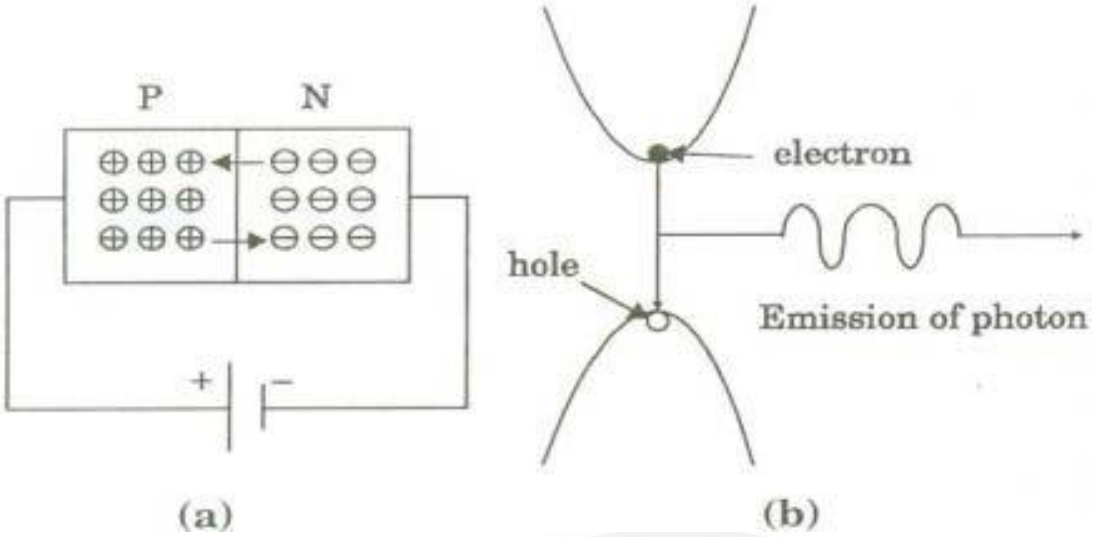


fig:2.10.1 (a)semiconductor laser principle,(b)Emission of photon

photon, in turn may induce another electron in the conduction band (CB) to valence band (VB) and thereby stimulate the emission of another photon.

Construction:

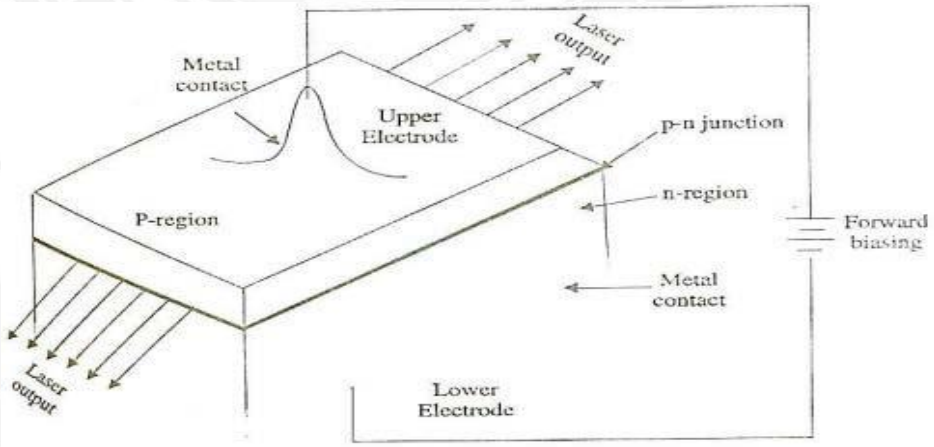
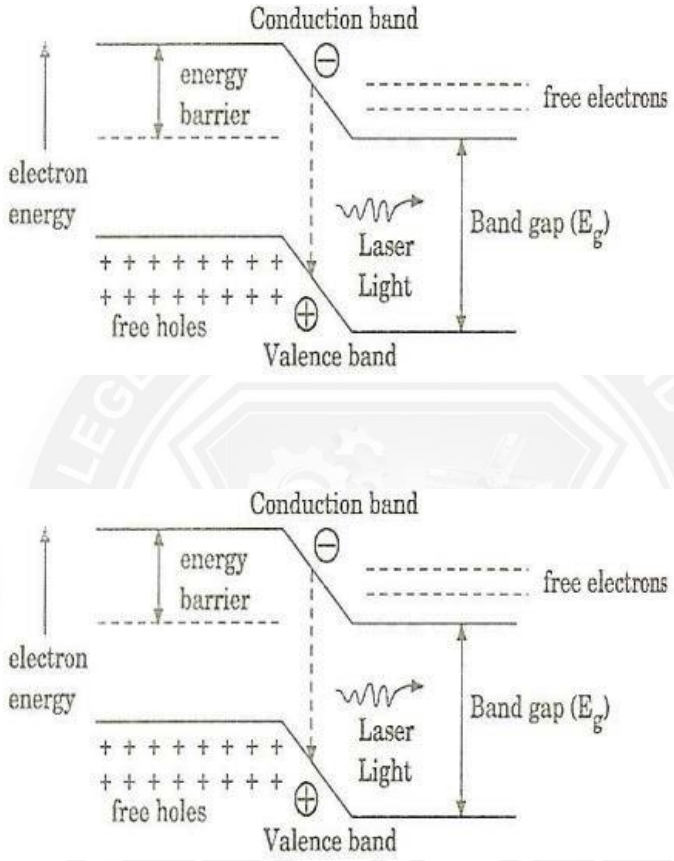


fig:2.10.2 Homojunction Semiconductor laser

The active medium is a p-n junction diode made from a single crystalline material i.e. Gallium Arsenide in which p-region is doped with germanium and n-region with Tellurium. The thickness of the p-n junction layer is very narrow so that the emitted laser radiation has large divergence. The junctions of the ‘p’ and ‘n’ are well polished and are parallel to each other as shown in figure. Since the refractive index of GaAs is high, it acts as optical resonator so that the external mirrors are not needed. The upper and lower

electrodes fixed in the 'p' and 'n' region helps for the flow of current to the diode while biasing.

Working



1. Fig:2.10.3 Band gap diagram

1.The population inversion in a p-n junction is achieved by heavily doping 'p' and 'n' materials, so that the Fermi level lies within the conduction band of n type and within the valence band of 'p' type as shown in figure.

2. If, the junction is forward biased with an applied voltage nearly equal to the band gap voltage, direct conduction takes place. Due to high current density, active region is generated near the depletion region.
3. At this junction, if a radiation having frequency (v) is made to incident on the p-n junction then the photon emission is produced as shown in figure.
4. Thus the frequency of the incident radiation should be in the range

$$\frac{Eg}{h} < \frac{EF_C - EF_V}{h}$$

5. Further, the emitted photons increase the rate of recombination of injection electrons from

the n region and holes in p region by inducing more recombination.

6. Hence the emitted photons have the same phase and frequency as that of original inducing photons and will be amplified to get intense beam of LASER.
7. The wavelength of emitted radiation depends on i) the band gap and ii) the concentration of donor and acceptor atoms in GaAs.

Advantages

i) It is easy to manufacture the diode.

ii) The cost is low.

Disadvantages

i) It produces low power output.

ii) The output wave is pulsed and will be continuous only for some time.

iii) The beam has large divergence.

iv) They have high threshold current density.

Applications

1. It is widely used in fibre optic communications
2. It is used to heal the wounds by IR radiation.
3. I t is also used as a pain killer.
4. It is used in printers, CD writing and reading.

Heterojunction Semiconductor LASER (GaAlAs)

Characteristics

Type	- Heterojunction Semiconductor laser
Active medium	– p-n junction diode (with various layers)
Active centre	- Recombination of electrons and holes
Pumping method	- Direct pumping
Optical Resonator	- Polished junctions of diode
Power output	- 10 mW
Nature of output	- Continuous waveform
Wavelength	- 8000 Å
Band gap	- 1.55 eV

Principle:

The electron in conduction band combines with a hole in the valence band and hence the recombination of electron and hole produces energy in the form of light. This photon, in turn may induce another electron in the conduction band (CB) to valence band (VB) and thereby stimulate the emission of another photon.

Construction:

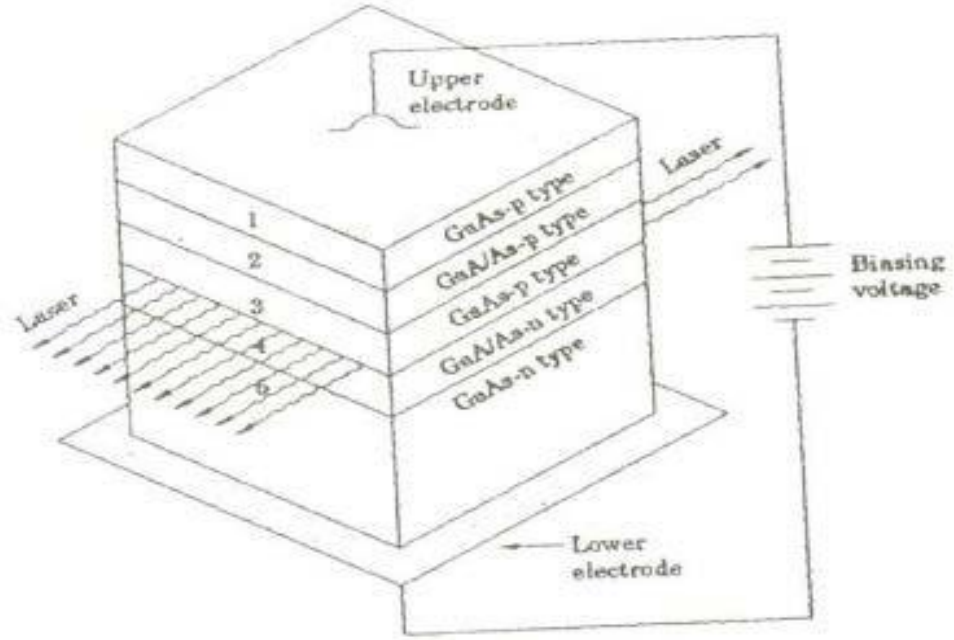


Fig 2.10.4 Heterojunction semiconductor laser

It consists of five layers as shown in figure. A layer of GaAs- p type (3rd layer) which has a narrow band gap will act as the active region. This layer (3rd layer) is sand witched between the two layers having wider band gap viz. GaAlAs – p-type (2nd layer) and GaAlAs – n-type (4th layer). A contact layer made of GaAs-p-type (1st layer) is made to form at the top of the 2nd layer for necessary biasing. All these four layers are grown over the substrate (5th layer) made of GaAs-n-type. The junctions of GaAs-p-type (3rd layer) and GaAlAs-n-type (4th layer) are well polished and hence it acts as an optical resonator. The upper and lower electrode helps in forward biasing the diode.

Working

The working of a hetero junction laser is similar to that of the working of a homo junction laser.

1) The diode is forward biased with the help of upper and lower electrodes.
2) Due to forward biasing the charge carriers are produced in the wide band gap layers (2 and 4).

3) These charge carriers are injected into the active region(layer 3).

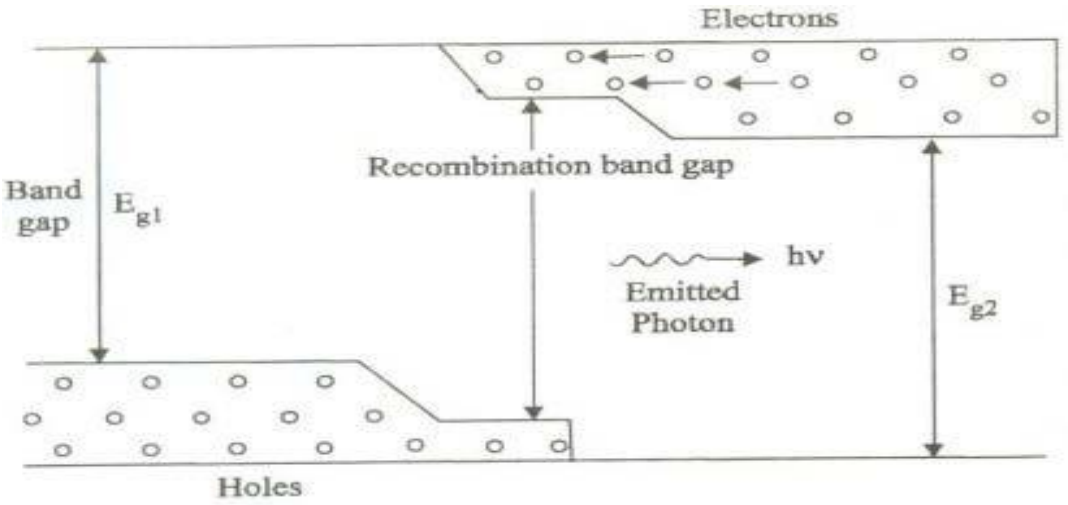


Fig 2.10.4 Band gap diagram

The charge carriers are continuously injected from 2nd and 4th layer to the 3rd layer, until the population inversion is achieved.

4) At this state some of the injected charge carriers recombines and produces spontaneously emitted photons.
5) These spontaneously emitted photons stimulate the injected charge carriers to emit photons.
6) As a result, more number of stimulated emissions arises and thus large number of photons is produced.
7) These photons are reflected back and forth at the junction and hence an intense, coherent beam of LASER emerges out from the P-N junctions of active region i.e. between layr-3 and layer-4 as shown in figure.

Applications of LASER

1. It is used in microelectronics.
2. It is used to deposit semiconductor films on dielectric substrate.
3. High power laser is used to write the data in the CD/DVD.
4. Laser is used as a tool to cut thin metal sheets by property of focusing.
5. It is used make weld, drill and perforate holes, even up to 0.2 to 0.5 μm of thickness.
6. It is used in the treatment of detached retina.
7. It is used to coagulation in diabetic retinopathy.
8. It is used in the treatment of nerves in skull and spine.
9. It is used in the treatment by coagulation of lower gastro intestinal fat.
10. Removal of skin imperfections by laser irradiation.
11. It is used to fallopian tube reconstruction.
12. It is also used in surgery.