UNIT – II WAVES AND OPTICS

TOPIC - V SEMICONDUCTOR LASER

5.11 HOMOJUNCTION SEMICONDUCTOR LASER

Characteristics of Homojunction laser

Type – Homojunction semiconductor laser

Active medium – PN junction diode

Active centre – Recombination of electrons and holes

Pumping method – Direct pumping

Optical resonator – junctions of diodes- polished

Power output – The power output from this laser is 1mW.

Nature of output – The nature of output is continuous wave or pulsed output

Wavelength emitted – 8400 – 8600 A°

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 to valence band and there by stimulate the emission of another photon.

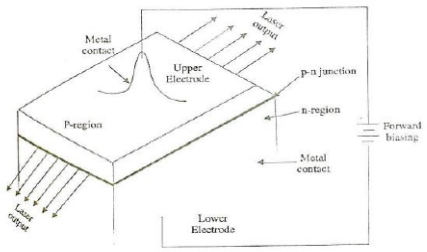

Fig.5.13

Construction

The active medium is a p-n-junction diode made from a single crystalline material ie. 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 5.13. 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

(i) 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 5.14.

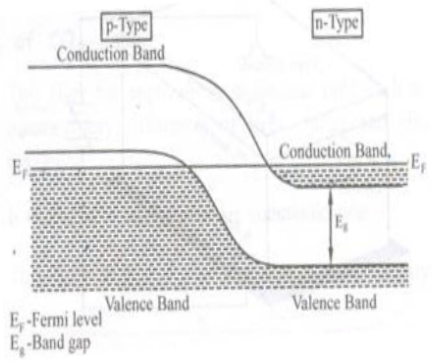

Fig.5.14

(ii) 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.

(iii)At this junction, if a radiation having frequency (γ) is made to incident on the p-n-junction then the photon emission is produced as shown in figure5.15.

Thus the frequency of the incident radiation should be in the range

$$E_g < \gamma < \frac{(E_{F_C} - E_{F_V})}{h}$$

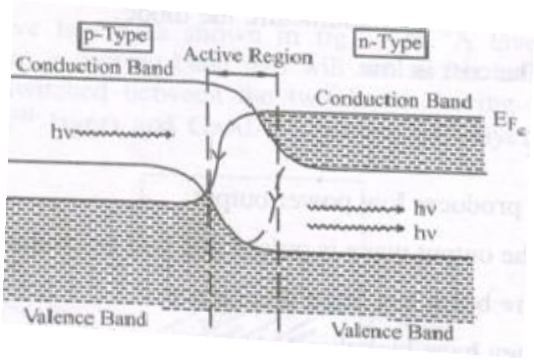

Fig.5.15

(iv)Further the emitted photon increases the rate of recombination of injected electrons from the n region and holes in p region by inducing more recombination. 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.

(v) The wavelength of emitted radiation depends on i. the band gap and ii. The concentration of donor and acceptor atoms in GaAs,

1. Calculation of wavelength

Band gap of GaAs = 1.44ev

$$E_g = h\gamma = h\frac{c}{\lambda}$$

$$\lambda = \frac{hc}{E_g}$$

$$= \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{1.44 \times 1.6 \times 10^{-19}}$$

$$= 8626\ A^{\circ}$$

The wavelength is near IR region.

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.

5.12 HETEROJUNCTION SEMICONDUCTOR LASER

Characteristics of Hetero junction semiconductor laser

Type - Hetero junction semiconductor laser

Active medium - p-n-junctions with various layers

Active centre – Recombination of electrons and holes

Pumping method – Direct pumping

Optical resonator – Junctions of diodes- polished

Power output – The power output from this laser is 10mW.

Nature of output – continuous wave form

Band gap – 1.55ev

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 to valence band and there by stimulate the emission of another photon.

Construction

It consists of five layers as shown in figure 5.16. A layer of GaAs- p-type (3rd layer) which has narrow band gap will act as the active region. This layer (3rd layer) is sandwitched between the two layers having wider band gap viz. GaAlAs – p-type (2nd layer) and GaAlAs – n-type (4th layer).

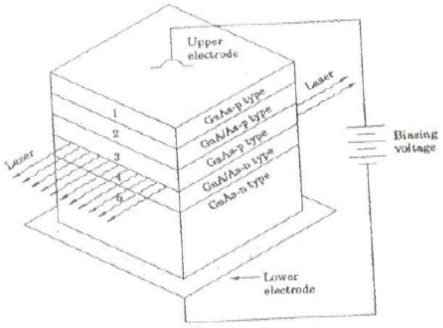

Fig.5.16

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 laters 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 electrodes help in forward biasing the diode.

Working

Working of a heterojunction laser is similar to that of the working of a homojunction laser.

(i) The diode is forward biased with the help of upper and lower electrodes.

(ii) Due to forward biasing the charge carriers are produced in the wide band gap layers (2 and 4).

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

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

(v) At this state some of the injected charge carriers recombines and produces spontaneously emitted photons.

(vi) These spontaneously emitted photons stimulate the injected charge carriers to emit photons.

(vii) As a result more number of stimulated emissions arises and thus large number of photons is produced.

(viii) 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 ie. Between layer-3 and layer-4 as shown in figure.

(ix) The wavelength of the emitted radiation is given by $\lambda = \frac{hc}{E_g}$

$$= \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{1.55 \times 1.6 \times 10^{-19}}$$

$$= 8014\ \text{A}^{\circ}$$

The wavelength lies IR region.

Advantages

i. Power output is high.
ii. It produces continuous wave output.
iii. It has high directionality and high coherence.
iv. It has low threshold current density compared to homojunction laser.
v. These diodes are highly stable and have longer life time.

Disadvantages

i. Cost is higher than homojunction laser.
ii. Practical difficulties arise while growing the different layers of p-n junction.