4.17 Semiconductor Laser

Q.27 Describe the construction and working of semiconductor laser.

☞ **[VTU : Aug.-10, Jan.-15, Marks 8]**

Ans. : Semiconductor Laser :

Principle :

When a P-N junction is forward biased, the conduction band electrons from N-type combine with the valence band holes in the depletion region and radiation is emitted. For silicon and germanium junctions, the radiation is in infrared whereas for materials like Gallium Arsenide (GaAs) and Gallium Arsenic Phosphide (GaAsP) the radiation is in the visible region the P-N junction is heavily doped and a large current is made to flow through the junction to create population inversion. Laser can be obtained by using a resonant cavity for such a junction.

Construction :

Metallic contacts are provided to the P and N types in a heavily doped P-N junction diode. Two opposite faces which are perpendicular to the plane of the junction are polished and made parallel to each other. These parallel faces constitute the resonant cavity and laser is obtained through these faces as shown in Fig. Q.27.1. The remaining two faces are roughened to prevent lasing action in that direction.

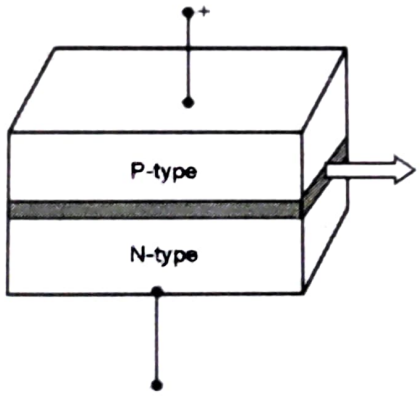

Fig. Q.27.1

Working :

As the P and N types are heavily doped, the fermi level (E_F) in N type lies in the conduction band and in P-type it lies in the valence band. The fermi level is uniform throughout the unbiased diode as shown in Fig. Q.27.2.

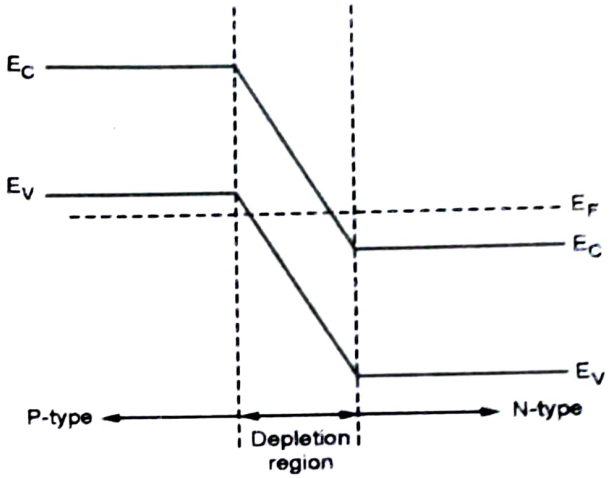

Fig. Q.27.2

When the junction is forward biased the energy levels shift as shown in Fig. Q.27.2. The width of depletion region decreases due to injection of electrons and holes. At low forward currents, the electron hole recombination causes spantaneous emission of radiation and the diode acts as a LED. When current is increased and reaches a threshold value , population inversion is achieved in the depletion region due to large concentration of electrons in conduction band and holes in valence band . The narrow region where population inversion is achieved in the depletion region due to large concentration of electrons in conduction band and holes in valence band. The narrow region where population inversion is achieved becomes the active region where lasing action takes place. The forward bias applied to the junction is thus the pumping mechanism which produces population inversion.

The photons travelling in the junction along the resonant cavity stimulate recombination of electron-hole pairs due to which the intensity of coherent light builds up along the axis of cavity.

The semiconductor lasers have low power consumption are compact and highly efficient. But the laser output is less monochromatic and more divergent compared to other lasers.

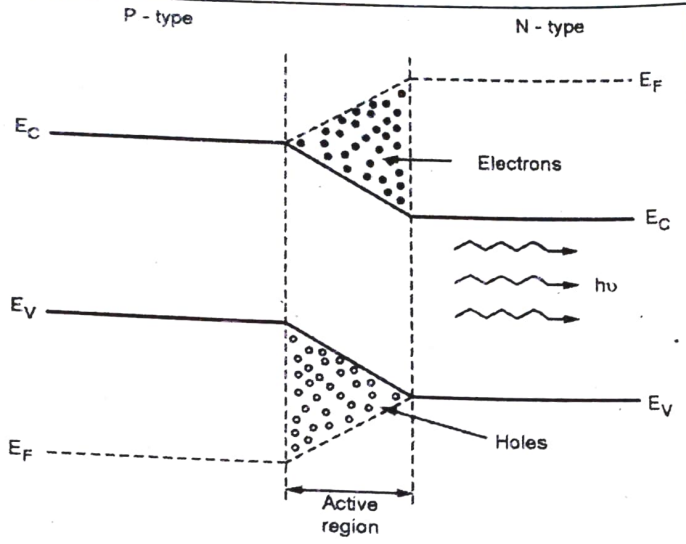

Fig. Q.27.3

4.18 Applications of Lasers

Q.28 Describe briefly the application of lasers in welding, cutting and drilling.

☞ [VTU : Aug.-07,09, Jan.-18, Marks 6]

Ans. : Applications of Lasers

A) Industrial and Engineering Applications

i) **Welding :** The two metal plates to be welded are held in contact at their edges as shown in Fig. Q.28.1 and a high power laser is focussed on the line of contact. The metal at the line of contact melts and solidifies on cooling which causes the two plates to stick together. As the laser can be focussed to a very sharp point, the heat affected area is very small. Hence laser welding does not cause distortion of the plates. Also, it is a contact - less procedure.

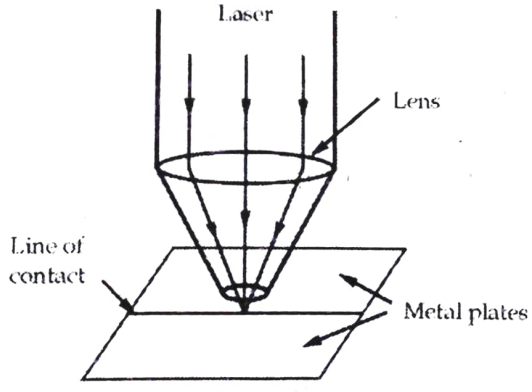

Fig. Q.28.1

Hence there is no possibility of introducing impurities. Laser welding is commonly used in automobile, ship building and aircraft manufacturing industries. CO_2 and NdYAG lasers are used for this purpose.

ii) **Cutting :** Cutting of metal sheets is achieved using high power lasers like NdYAG or CO_2 lasers. The laser is focussed on the metal sheet and a jet of oxygen is blown on the spot. A significant part of the energy required for cutting is supplied by burning of the metal in oxygen. The oxygen jet also blows away the vapourized metal and also cools the adjacent edges. An arrangement of gas laser cutting is shown in Fig. Q.28.2 Higher cutting speeds have been achieved with lasers compared to other conventional methods. Laser cutting produces higher quality of the cut edges.

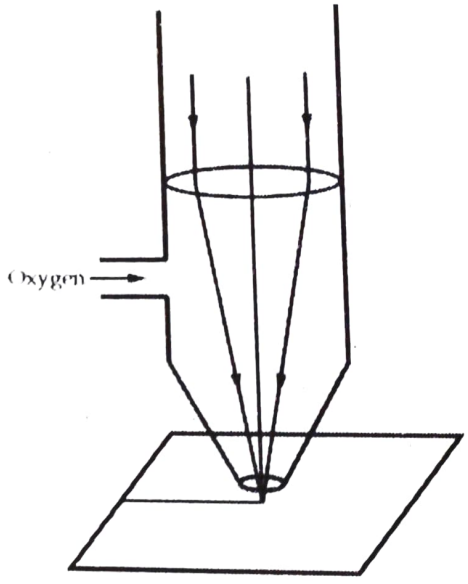

Fig. Q.28.2

iii) **Drilling :** Holes can be drilled into materials using high power pulsed lasers of 10^{-4} to 10^{-3} s duration. The laser pulse evaporates the material which leaves a hole in its place. NdYAG laser is commonly used for this purpose. Laser drilling has a very high degree of precision and holes can be drilled in any direction. As the laser can be focussed to a very fine spot, very small holes can be drilled having diameters of the order of a few microns. As there are no mechanical vibrations, holes can be drilled very close to the edges without damaging the metal plates.