2.7 Lasers :

- The term **Laser** stands for light amplification by stimulated emission of radiation. Here the word **light** stand for the electromagnetic radiation which covers the range from ultraviolet region to the infrared region.
- The light has a dual nature. It consists of a wave nature and the energy. The energy contained by the light means the number of photons contained by that light.
- The laser light is '**monochromatic**' in nature that means this light is having a single colour or single wavelength (monomeans one and chroms means colour) Similarly this light is coherent in the nature, that means all the wavelengths contained in laser light are in the same phase.
- This is the major advantage of laser over ordinary light sources.
- In case of the lamps, only a small portion of the light output from the lamp is the visible region. For example in case of 100w bulb only 10% of light is in the visible region. The remaining part of light is in the invisible range and some part of this light is radiated out as a heat.
- But in case of lasers the maximum light is in the visible region. similary as compared to the light output from other devices the laser light is more sharper.
- And as the light is having more sharper line, the power output will be more.
- The first successful laser was designed by Maiman in 1960. After that several improvements were done and now a days various types of laser are available.
- That are ruby lesers, gaseous lasers power lasers, semiconductor lasers etc.

2.7.1 Basic Steps Required to Form Laser Beam :

There are generally three processes :

(i) Absorption.

(ii) Spontaneous emission.

(iii) Stimulated emission.

(i) Absorption :

- Under normal condition the tendency of electrons in case of the semiconducting material is to stay at the lower energy level. This lower energy

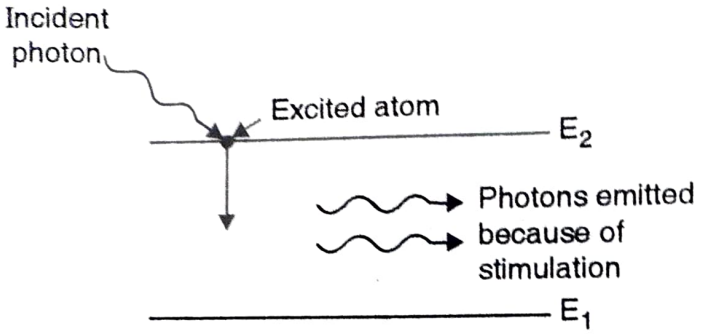

Fig. 2.16 : Stimulated emission

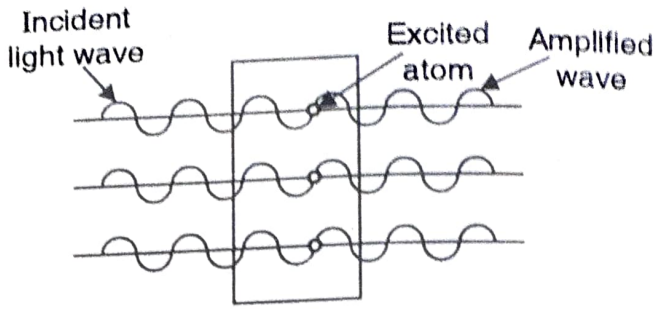

Fig. 2.17 : Amplification of light wave

- Consider a box containing the excited atoms. Now if a photon that means a light wave is applied to it as shown in Fig. 2.17 then the stimulated emission takes places and the light wave gets amplified.
- Here the important thing is that, the input light wave should be applied to excited atom before the occurrence of spontaneous emission process. Otherwise no amplification of input wave will take place, rather in this case output wave will be having some amplitude as that of input wave.
- If instead of excited atoms the atoms at the lower energy level are present in the box then these atoms absorbs the energy from input wave and the amplitude of input wave gets reduced. So in this case to cause the amplification two conditions are necessary :

(a) The input light wave (photons) should strike the excited atoms before the occurrence of spontaneous emission.

(b) In the total structure the number of excited atoms should be more than that of the atoms present at the ground level.

- The process in which the number of excited atoms made larger than that of the atoms present at ground state is called **"Population inversion"**.
- Similarly the time period for which the atoms present in this excited state should be made longer. This again makes easier to cause the stimulated emission.
- Thus in case of stimulaed emission if number of atoms at the excited state are more, more number of photons are emitted. Thus causing amplification of light. All these photons are in same phase and are traveling in the same direction. Now this amplified light wave is called laser beam which is coherent and monochromatic in nature.

Advantages of laser over other light sources :

(1) Laser light has narrow spectral band width.

(2) Light is coherent and monochromatic.

(3) Laser light is having good directionality.
(4) More percentage of the laser light is in the visible range as compared to conventional lamps.
(5) Laser has high quantum efficiency.
(6) Light from laser can travel several kilometers distance with very small divergence.
(7) Laser light has high modulation rate.
(8) A very fine spot of the light can be obtained at the detector, so laser is considered as a point light source.
(9) Laser light has excellent stability.
(10) Laser light can be modulated externally or it has ability of direct modulation.

2.7.2 Laser Diodes :

- The structure of semiconducting material is different than that of insulators and good conductors.
- In semiconducting material no single energy level is present but there are broad bands of energy levels. These energy levels are not associated with the individual atoms, but they are associated to the material.
- In case of insulators the valance band (lowest energy level) is completely filled and the conduction band (highest energy level) is empty. And in case of conductors there is over lap of valance band and conduction band.
- So in this case the conduction is possible. In contrast to this conductors and insulators the energy gap is less for the semiconductors. This is 2 to 3 eV so the thermal excitation will cause the motion of electrons from valance band to conduction band and thus the conduction is possible.
- Similarly if the thermal excitation (i.e. excitation taking place because of increase in temperature) is sufficient then the stimulated emission can occur and the laser beam is formed.
- Thus to causes the stimulated emission process population inversion should be done. That means the number of electrons should be moved from valance band to the conduction band.
- The semiconductors having more number of electrons in conduction band than that of valance band is called "degenerate semiconductors".
- The semiconductors in which no dopents are used are called as intrinsic semiconductors. In this case the population inversion is done as shown in Fig. 2.18.

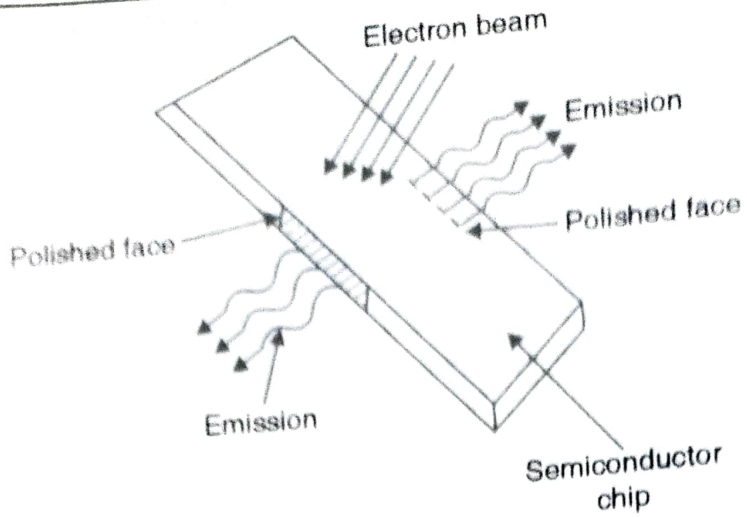

Fig. 2.18 : Emission of laser beam from a semiconductor chip

- Here an electron beam is used to heat the semiconductor chip as shown in Fig. 2.18. This electron beam gives out fast electrons nearly 100 keV strong. When this electron beam falls on the semiconductor chip, it penetrates into the semiconductor.
- This will cause the excitation of electrons from valance band to the conduction band. Thus the population inversion is done. Now as shown in Fig. 2.18 two faces of semiconductor chip are polished.

So the number oscillations for the photons takes place in this optical cavity until a resonant beam is formed. These photons are generated due to stimulated emission process. Thus the laser beam comes out from one of the faces of semiconductor chip. In this case that heat generated will be move because of highly concentrate electron beam So in this case a cooling system is required and always a pulsed operation is used instead of the continuous operation.

- In case of the semiconductors containing the impurities it is possible to cause the population inversion at still lower temperature.
- For the both cases discussed above i.e. the intrinsic semiconductors and dopped semiconductory, the cooling is required the efficiency of the system is less. So always p-n junction semiconductors are preferred.
- The lasers formed by joining p and n type of materials are called injection lasers The construction of injection laser is as shown in Fig. 2.19.
- This consists of a p-n junction made up of gallium Arsenide material. As shown in Fig. 2.19, this junction is forward biased, so the current starts flowing. It means the electrons starts moving from n side to p side and the holes starts moving from p side to the n side.
- Now similar to the LED the recombination o electron and holes takes place. It means that the electrons falls from conduction band to the valance band.

And while doing this they emits the photons. The two ends of this structure are made reflective as shown in Fig. 2.19. These two faces are called cleaved end faces. This is obtained by doing the polishing of the two faces. These two faces causes the number of reflections of photons until a resonant beam is formed.

- The resonant beam called as laser beam comes out from one of the cleaved end faces which is made less reflective.

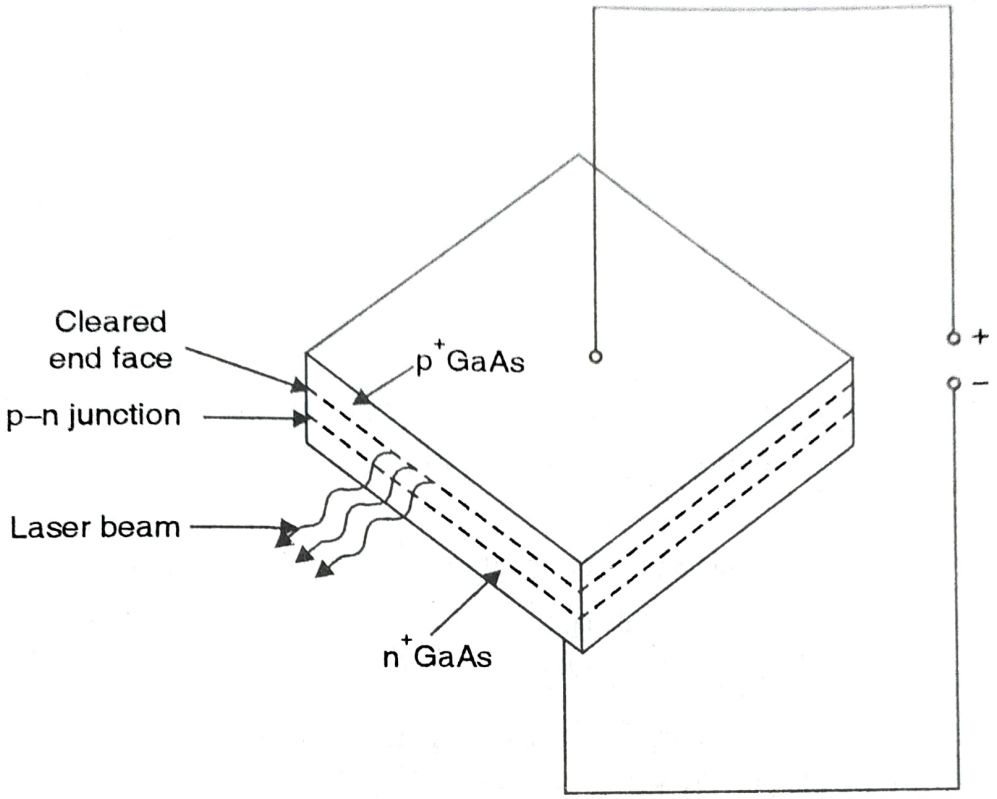

Fig. 2.19 : Construction of injection laser

- But to cause the stimulated emission a sufficient forward current is required. When the forward current is low then the radiation of light from this structure is because of the spontaneous emission process similar to the Ga As LED.
- But when the sufficient current is reached called as threshold current the stimulated emission takes place and the laser beam is generated. The light output verses current characteristics is as shown in Fig. 2.20.

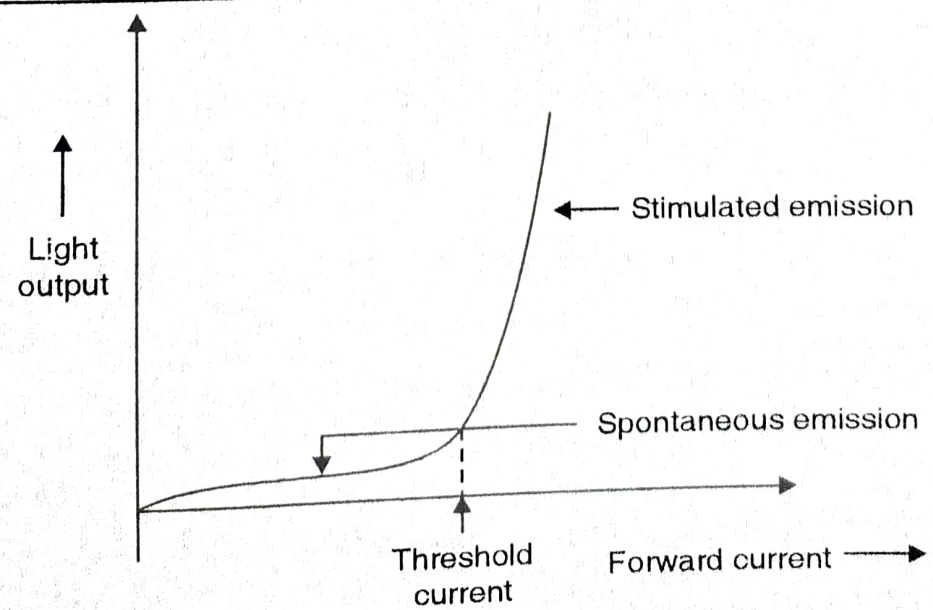

Fig. 2.20 : Light output Vs current characteristics

- The wavelength of this laser beam is from 0.82 μm to 0.9 μm .
- The radiation in this laser diode takes place in a cavity called as Fabry Perot resonant cavity.
- The approximate dimensions of this cavity are as follows :

  Longitudinal dimensions – 250 to 500 μm.

  Lateral dimensions – 5 to 15 μm.

  Transverse dimensions – 0.1 to 0.2 μm.

advantages :

(1) Efficiency is high. It is between 50% to 60%.
(2) The response time is fast.
(3) They posses higher data transmission rates.
(4) It has a narrow output spectrum.
(5) Emission from laser diode is more nearly a single frequency that means coherent in nature.
(6) They possess high bit rate and higher repeater spacing.
(7) They provides high launch power.
(8) They provides less distortion of the signal.
(9) Greater transmission distances are possible by using the laser diode.
(10) The dispersion is less.

Disadvantages :

(1) Heating problems are more so continuous operation is difficult.
(2) They are more temperature sensitive.
(3) The consturction is complicated.
(4) The laser diode increase the complexity of transmitter circuit.
(5) The life time is less This is because at high optical power densities the mechanical damage of facets may take place.

2.7.4 Factors Affecting the Operation of Light Sources :

- We have studied that generally LED's and laser diodes are used as light sources. For wide band analog operation the LED's having high radiance as well as laser diodes are used. But in this application the nonlinearities are pleasant in the output signal.
- Because of these nonlinearities an additional frequency components are present in the output signal so the output signal gets distorted. Generally there are two of non linearities :
  (1) Harmonic distortion
  (2) Intermodulation distortion.
- In order to reduce these nonlinearity effects the special design techniques are used at the receiver. This will reduce the total harmonic distortion by 30 to 40 dB.
- Both these optical sources are affected by higher operating current and high temperature. This will reduce the lifetime of optical sources. So it is preferred to operate these sources at low currents and low temperature.

2.7.5 Comparison between LED and Laser Diode :

Sr. No.	LED	Laser Diode
1.	Low efficiency.	High efficiency.
2.	Response time is slow.	Response time is fast.
3.	Lower data transmission rate.	Higher data transmission rate.
4.	Broad output spectrum.	Narrow output spectrum.
5.	Light beam is not coherent in nature.	Output beam is coherent.
6.	Lower bit rate.	Higher bit rate.
7.	Low launch power.	High launch power.
8.	Provides more distortion at output.	Provides less distortion.
9.	Used for lower transmission distances.	Used for greater transmission distances.
10.	Dispersion is more.	Dispersion is less.
11.	Less heating problems.	Heating problems are more.
12.	Less temperature sensitive.	More temperature sensitive.
13.	Simple construction.	Construction is complicated.
14.	With LED transmitter circuit is simple.	With this transmission circuit is complicated.
15.	Life time is more.	Life time is less.