

* BASICS of Laser and its Laser Mechanism *

LASER - The term Laser stands for Light amplification stimulated emission of radiation.

Basic process -

1) Spontaneous Emission -

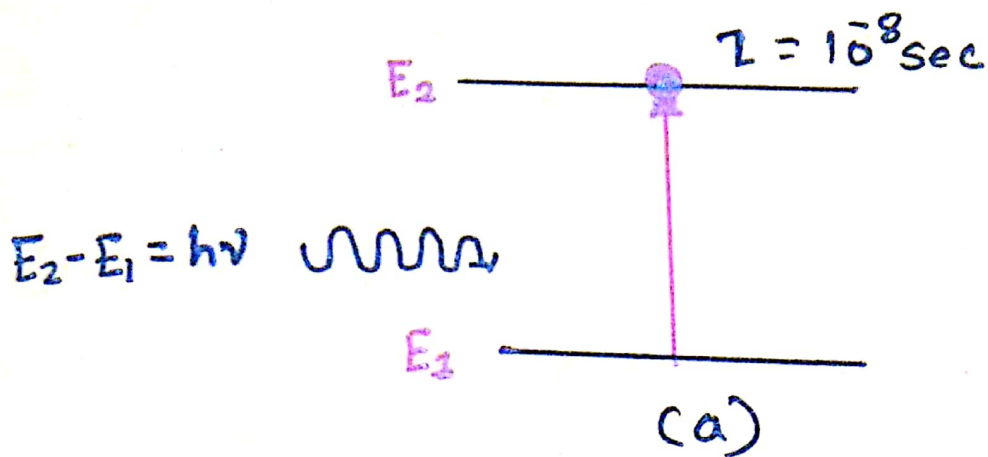
When a photon of energy $E = h\nu$ is incident on an atom, the atom absorbs the energy to rise to an excited state. The difference of the energy levels should be equal to the absorbed energy ($E_2 - E_1 = h\nu$).

Though the e^- stays in ground state for an ∞ time but remain in the excited state for a short time called the life time of the excited state ($\tau = 10^{-8} \text{ sec}$).

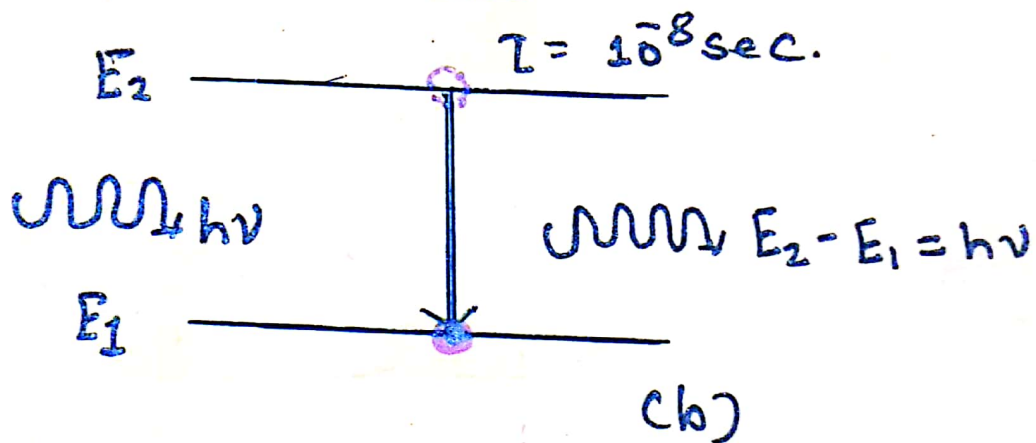
Energy levels for which the life time greater than 10^{-8} sec called metastable states.

The e^- which is in excited state E_2 spontaneously decays back to the lower energy level and radiates an equal to the ~~lower~~ energy level equal to $E_2 - E_1 = h\nu$ in the form of photon of energy $h\nu$. such an emission which is random in behaviour. depending only on the type of atom & transition is known as spontaneous emission. consider a fig. c. where the e^- is initially in the excited state energy level & emission is stimulated before the spontaneous emission occurs. excited atom is stimulated by a photon of exactly the same energy & the photon to be emitted. two photons are emitted of same energy.

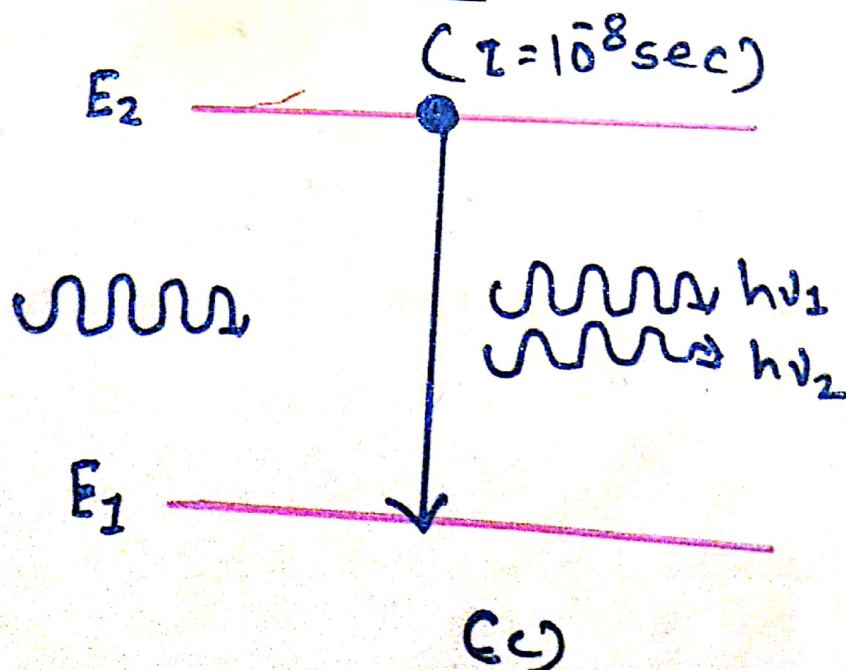
① Induced Absorption



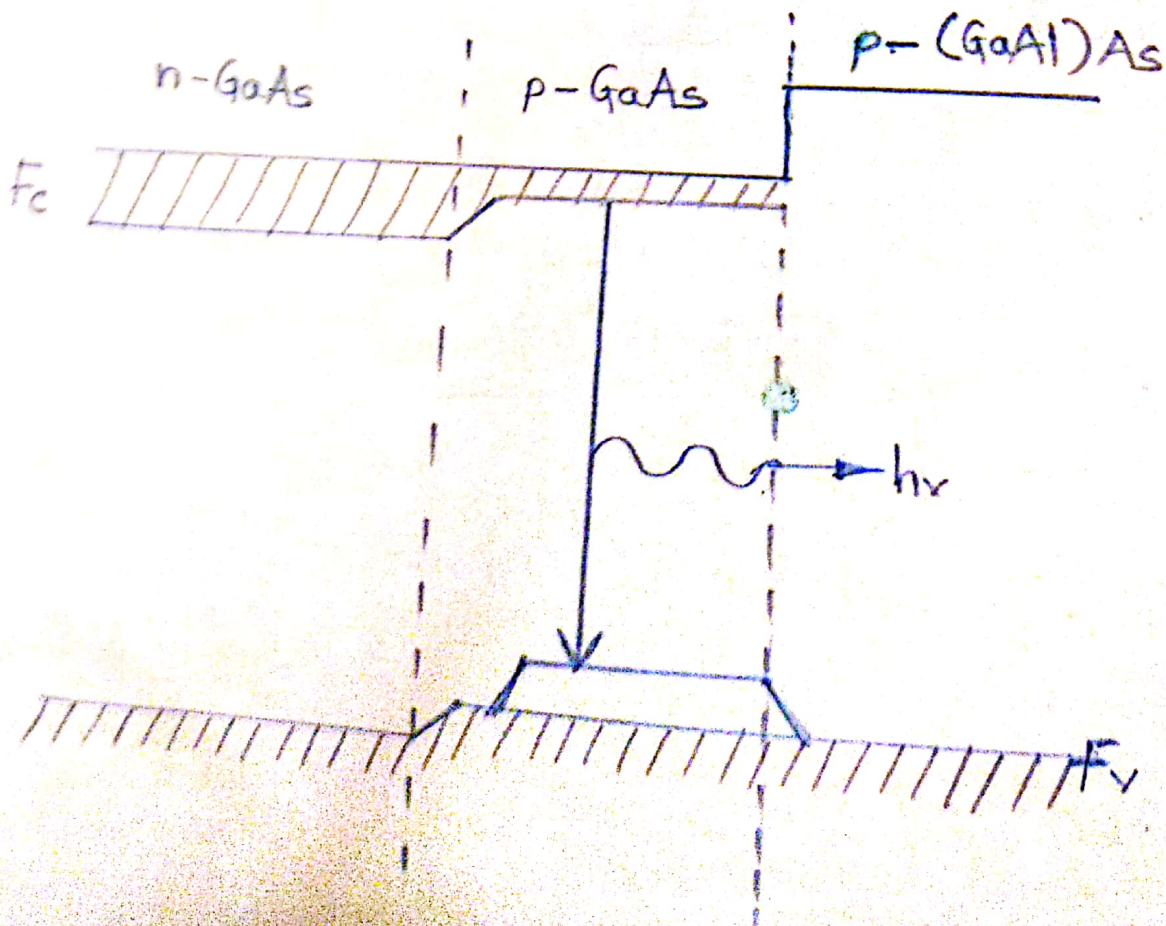
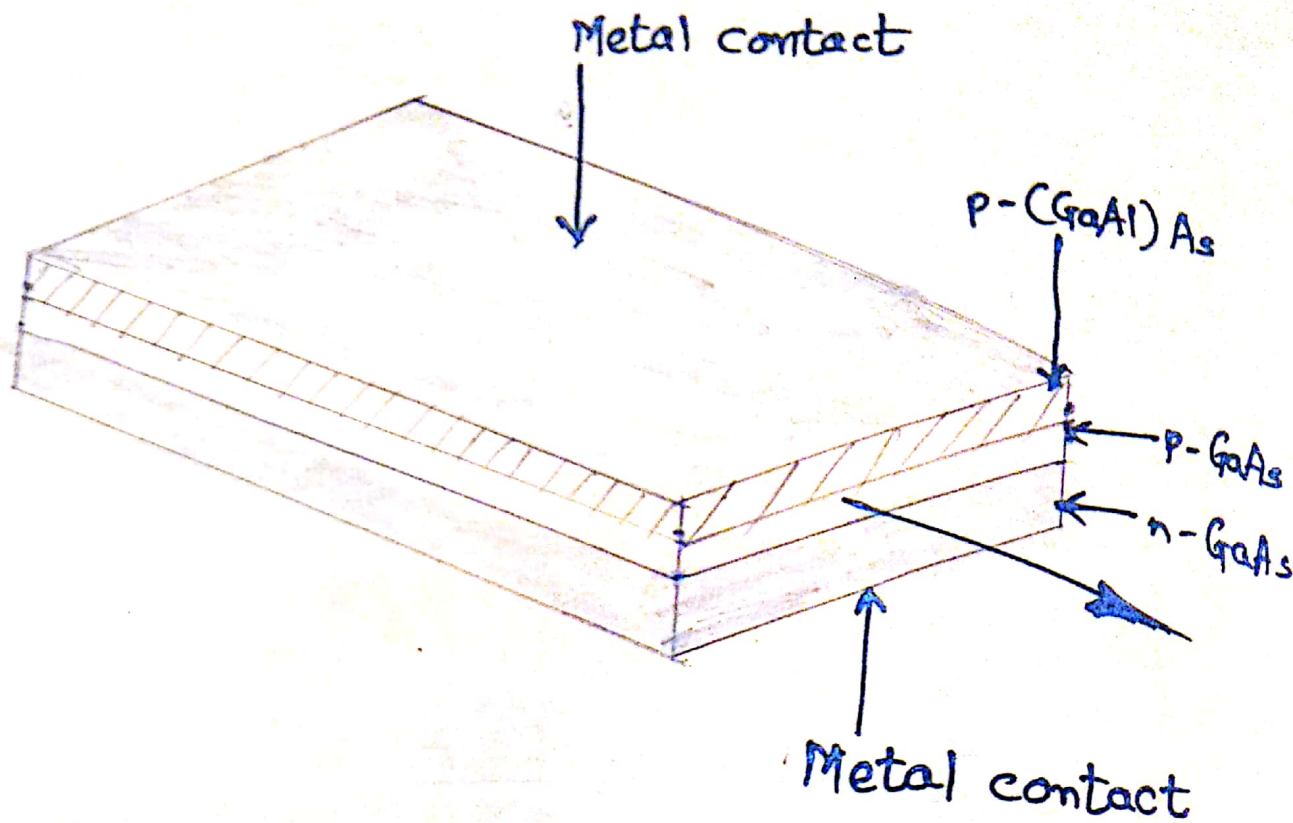
② Spontaneous Emission



③ Stimulated Emission -



*Single Heterojunction Laser



Basically diode laser can be classified in two categories.

- **Homojunction Semiconductor**: A simple diode laser which make use of semiconductor material on both side of junction.

- **Heterojunction semiconductor**: A diode laser which makes use of semiconductor material on two sides of junction.

Construction: the simplest of heterostructure is the single heterojunction layer.

1) Active layer of gas: It consist of an active layer of gas. where the P-n junction is located

2) Additional layer of gas (AlGaAs): the layer of (AlGaAs) is grown on top of P-region. this layer has higher band & has lower R.T. 2) the layer act as a barrier for injected carrier. & provide waveguide prop. 3) top & bottom faces have metal contact to pass current. 4) front & rear face work as resonator.

3) pump Working:

1) Active layer: lasing action occurs in p-GaAs layer at the centre

2) pumping machine: At forward bias, e^- & holes are injected in active region in high conc. when diode current reaches threshold value, carrier conc. in active layer reaches max. val

- Advantages. 1) due to change in R.T at boundary, p-GaAs & p-CGaAs. e^- are reflected back into active region.

2) the presence of hetero structure confine charge carrier into active region.

Stimulated Emission:- these spontaneous photon propagation in active layer stimulated conduction electron to jump into vacant state in valance band & produce stimulated photon.

2) the reflection of photons from polished ends within the active layer provide feedback for lasing action & laser oscillation starts.

3) After attaining sufficient strength, laser beam emerges out from diode.

Advantages of Heterojunction:

Due to change in R.I at the boundary P-GaAs & P-(GaAl) the laser light is trapped within the active region & travels in one direction only.

Advantages of Heterojunction laser:

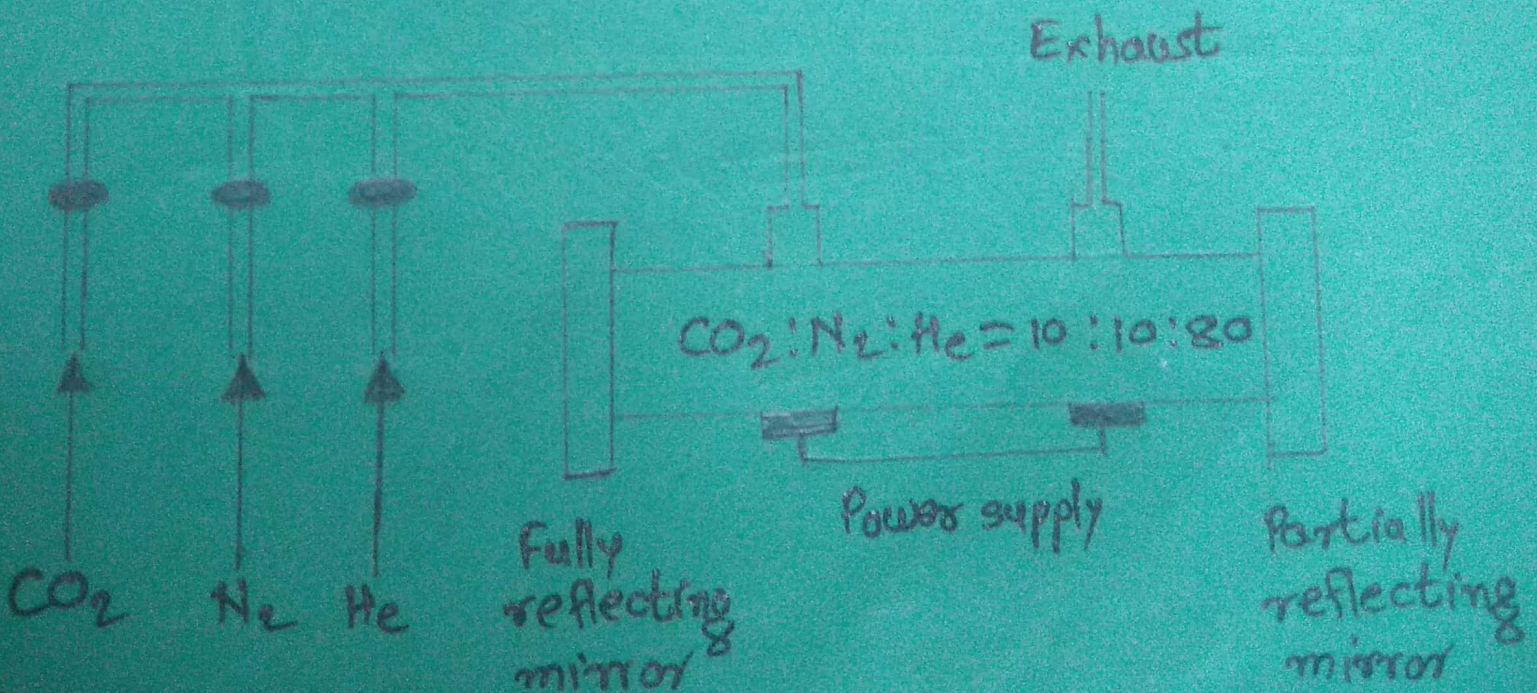
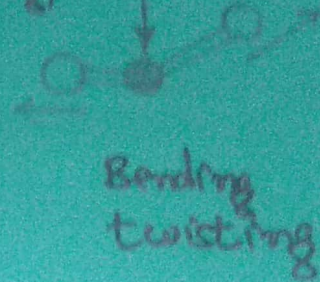
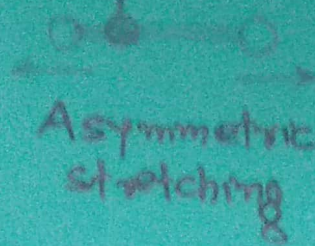
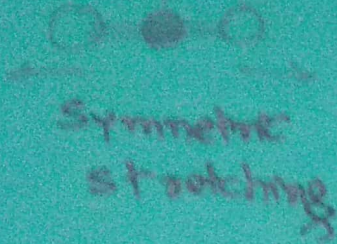
- High efficiency even at room 'temperature'
- less operating current is required.
- Threshold current density is less, due to which continuous laser output is possible.

Vibrational modes of CO₂ Carbon dioxide

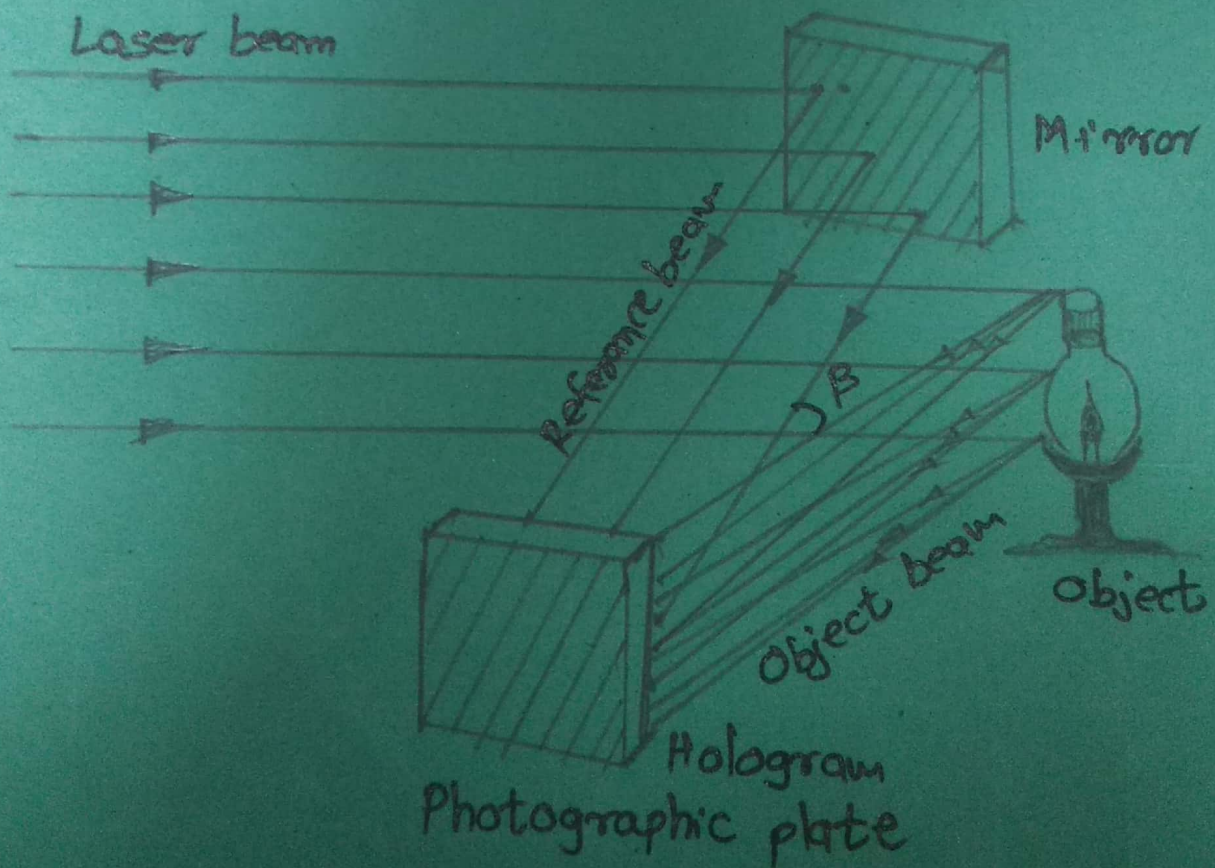
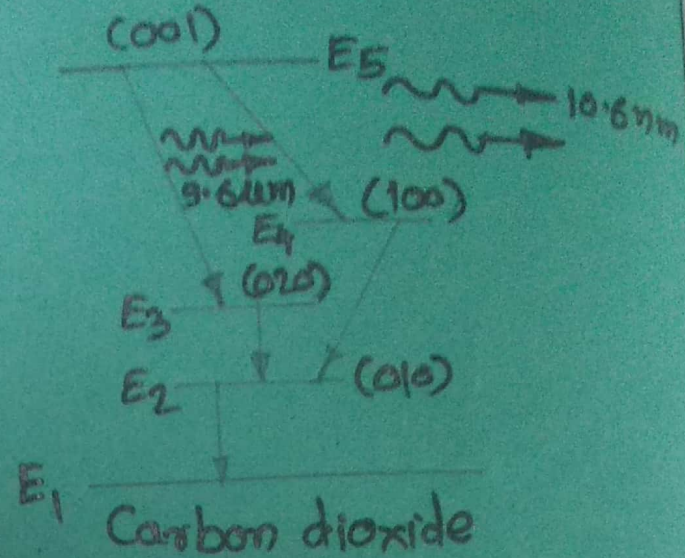
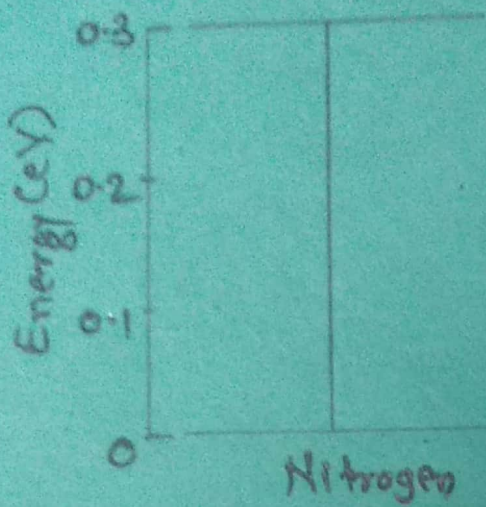


Stretching
Higher energy

Bending
Lower energy



Energy transfer through collisions



Gas Laser (CO_2) :-

- 1> the carbon dioxide (CO_2) laser is a molecular gas laser based on a gas mixture carbon dioxide, Helium & nitrogen as the gain medium.
- 2> depending on manuf. continuous output power varies between a few watt to hundred watt.
- 3> A CO_2 molecule is a linear molecule & with Carbon atom in the middle. It undergoes three independent vibration oscillation.
- 4> transition to the symmetric stretching mode & bending mode correspond to wavelength of $10.6 \mu\text{m}$ & $9.6 \mu\text{m}$ resp.

Construction of CO_2 laser:

- 1> the output power of CO_2 laser, depends on its diameter.
- 2> A mixture of CO_2 , Nitrogen & Helium is taken into a discharge tube powered by a by power supply.
- 3> Gases are filled inside the tube with pressure 10% CO_2 , 16% Nitrogen & 80% Helium.
- 4> fully reflecting mirror & partially reflecting mirror are fitted on the either side of the tube for recirculation of the laser light inside the tube.

Pumping: 1> Electric discharge is created in the laser tube. the energy of accelerating electrons is transferred to nitrogen & they accumulated to metastable state. 2> N_2 molecule collide in & CO_2 molecules are moved to excited E_5 level.

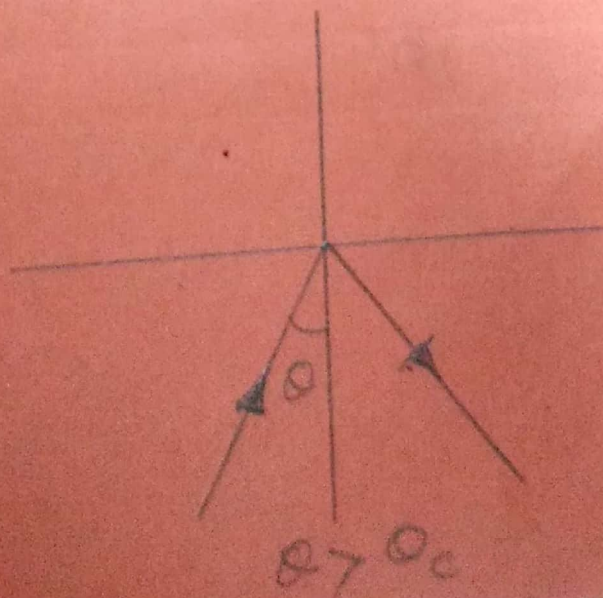
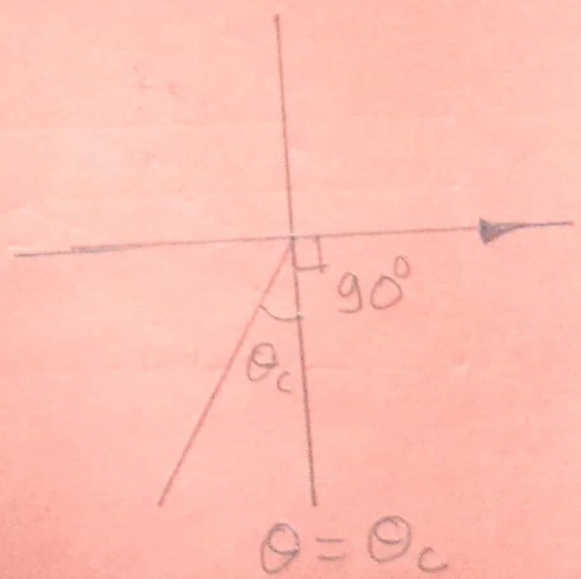
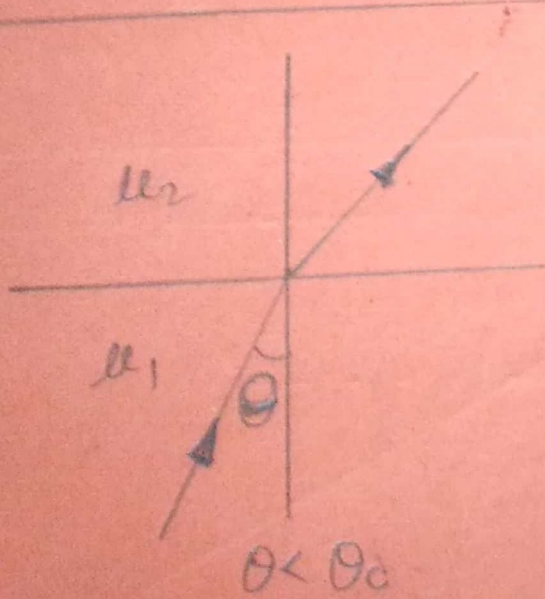
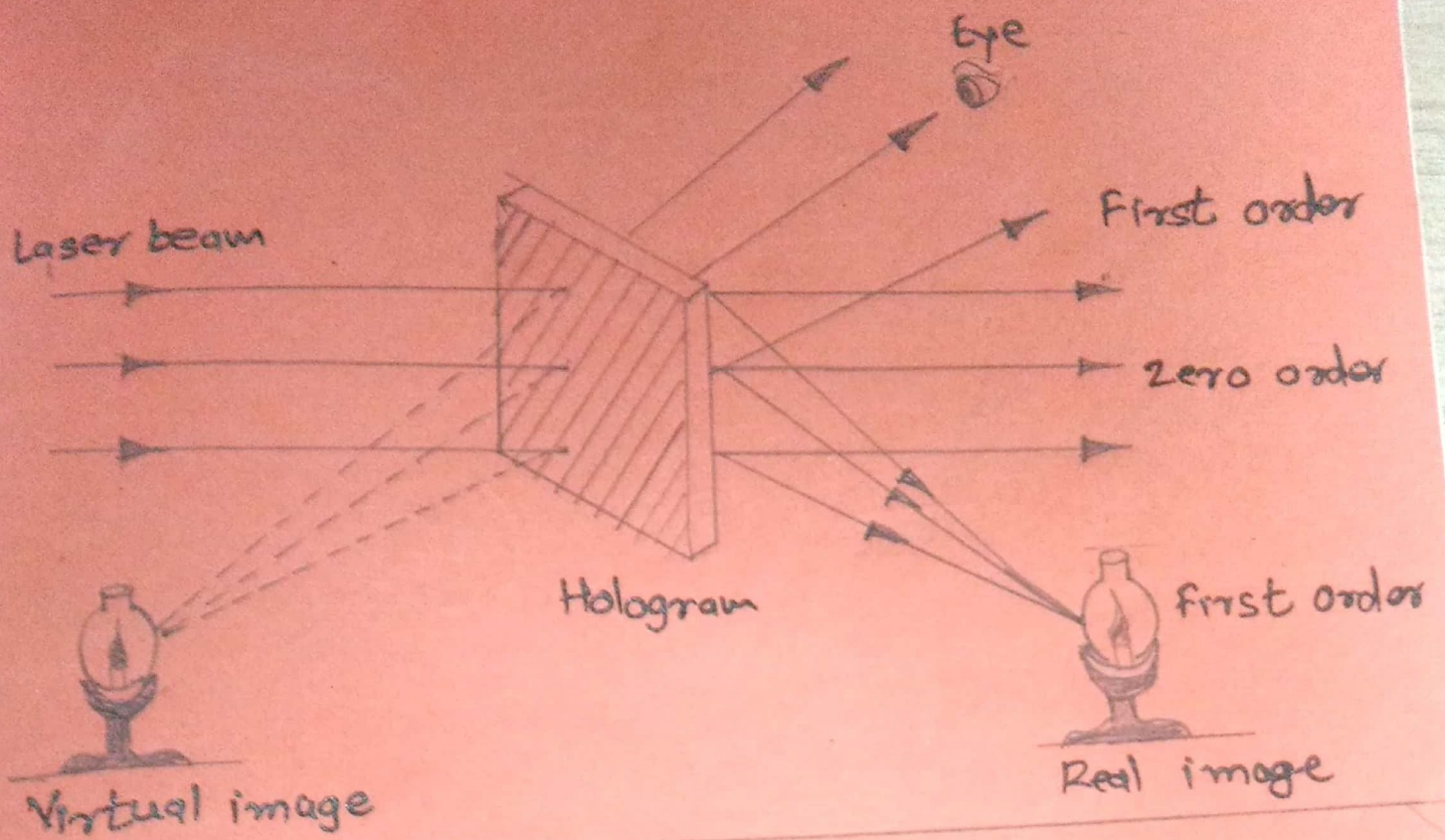
Population Inversion: E_5 is a higher energy level, while energy level E_3 & E_4 are lower metastable level of CO_2 due to buildup of CO_2 molecule in higher E_5 energy level, population inversion takes place in E_5 , & E_3 & E_4 energy levels.

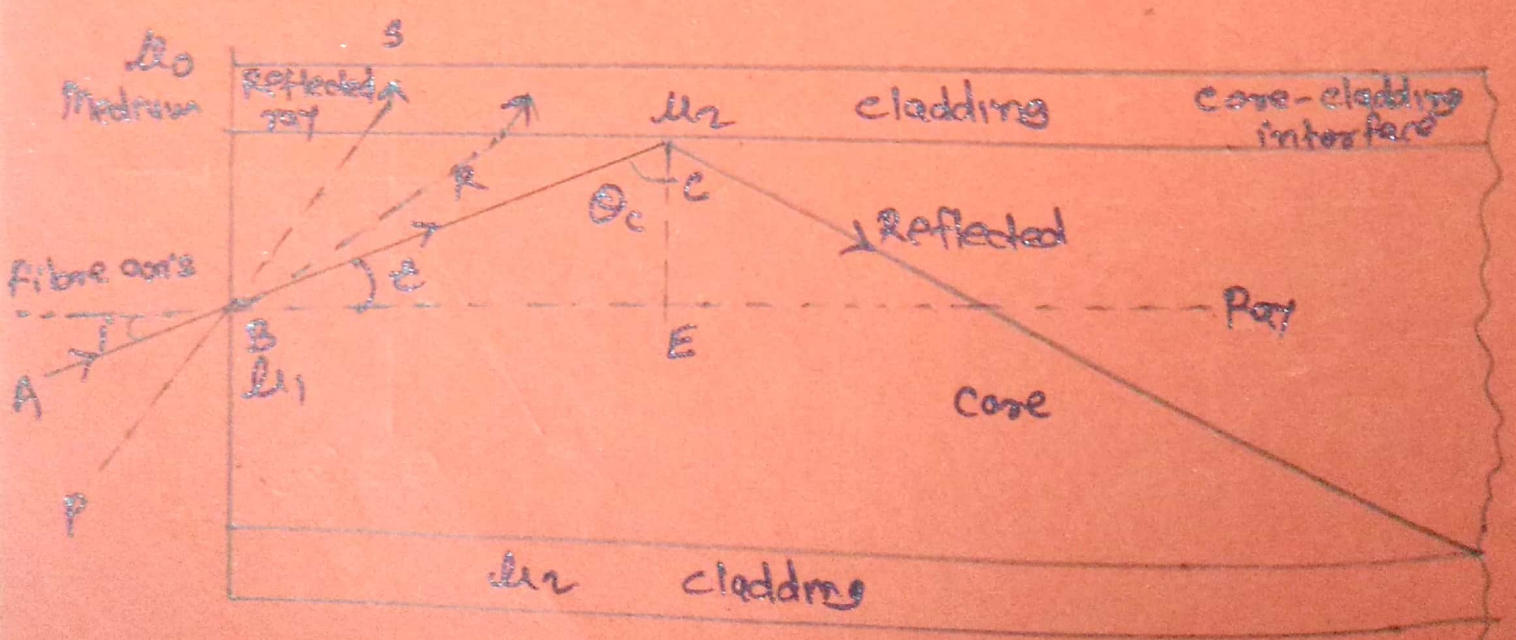
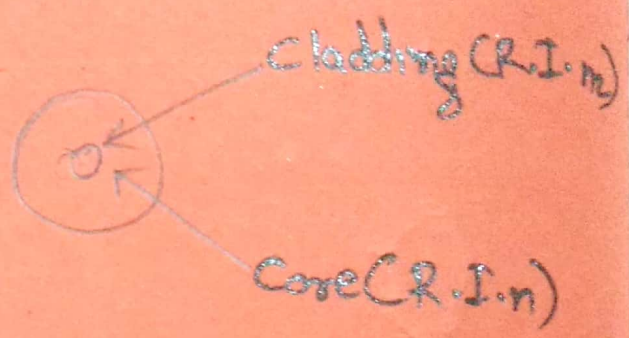
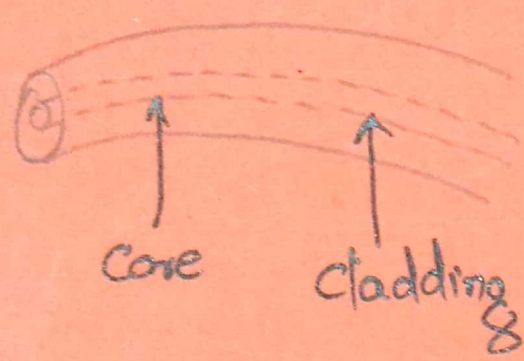
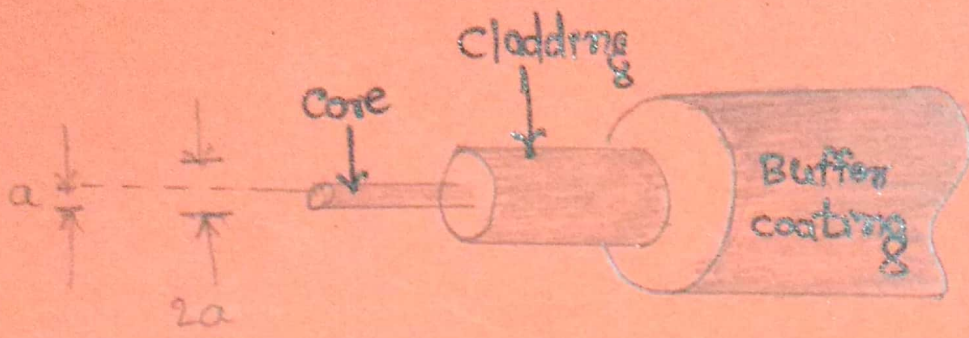
Lasing Action:

- 1) CO_2 is active medium for it & N_2 & He improve efficiency
- 2) recirculated photon build up along axis of discharge tube.
- 3) oscillation take place in betⁿ two vibrational level of CO_2 .
- 4) transition betⁿ $E_5 \rightarrow E_4$ produce IR radiation of wavelength 10.6 μm & betⁿ $E_5 \rightarrow E_3$ produce 9.6 μm .
- 5) CO_2 molecule in E_4 & E_3 level falls to lower energy level E_2 which is close to ground level Helium atoms collide with CO_2 molecule is E_2 level & reduce thier population.
- 6) the de-excited CO_2 molecule are again excited due to collision of nitrogen & are taken into upper excited state E_5 . this helps in maintaining continuous laser output

Advantages of CO_2 laser :-

- 1) Very high power output with efficiency 30-40% which better than HeNe & argon.
- 2) It operate continuous mode.
- 3) CO_2 laser are low cost per watt & have good beam quality.
- 4) It generate high power output which range from 10 Kw
- 5) used primarily for material processing application.





Application of Laser:-

Holography:- This is a technique of producing an interference pattern between a direct laser beam & a laser beam reflected from an object on a photographic plate. This pattern on the developed photographic plate, when illuminated with laser in proper manner, produces a 3D image of the object called 'hologram'.

Basic Technique: ① Hologram recording.

- 1) the recording of a hologram is achieved by superposition of 'the object wave' with another wave called 'the reference wave'.
- 2) the reference wave is usually a plane wave.
- 3) the resulting interference pattern is recorded on a photographic plate. As the shape of the object is very irregular, it results in a complicated fringe pattern. Thus a hologram is a record of a complicated interference fringe pattern.
- 4) Fig. shows a typical configuration used for recording a hologram. A portion of a coherent beam is allowed to be scattered by the object and the other portion is reflected by a mirror. The former corresponds to the object wave and the latter to the reference wave.
- 5) the object wave & the reference wave interfere and the resultant interference pattern is recorded on a photographic plate.
- 6) When the photographic plate which has recorded the intensity variation is developed, one obtains a hologram of the object.

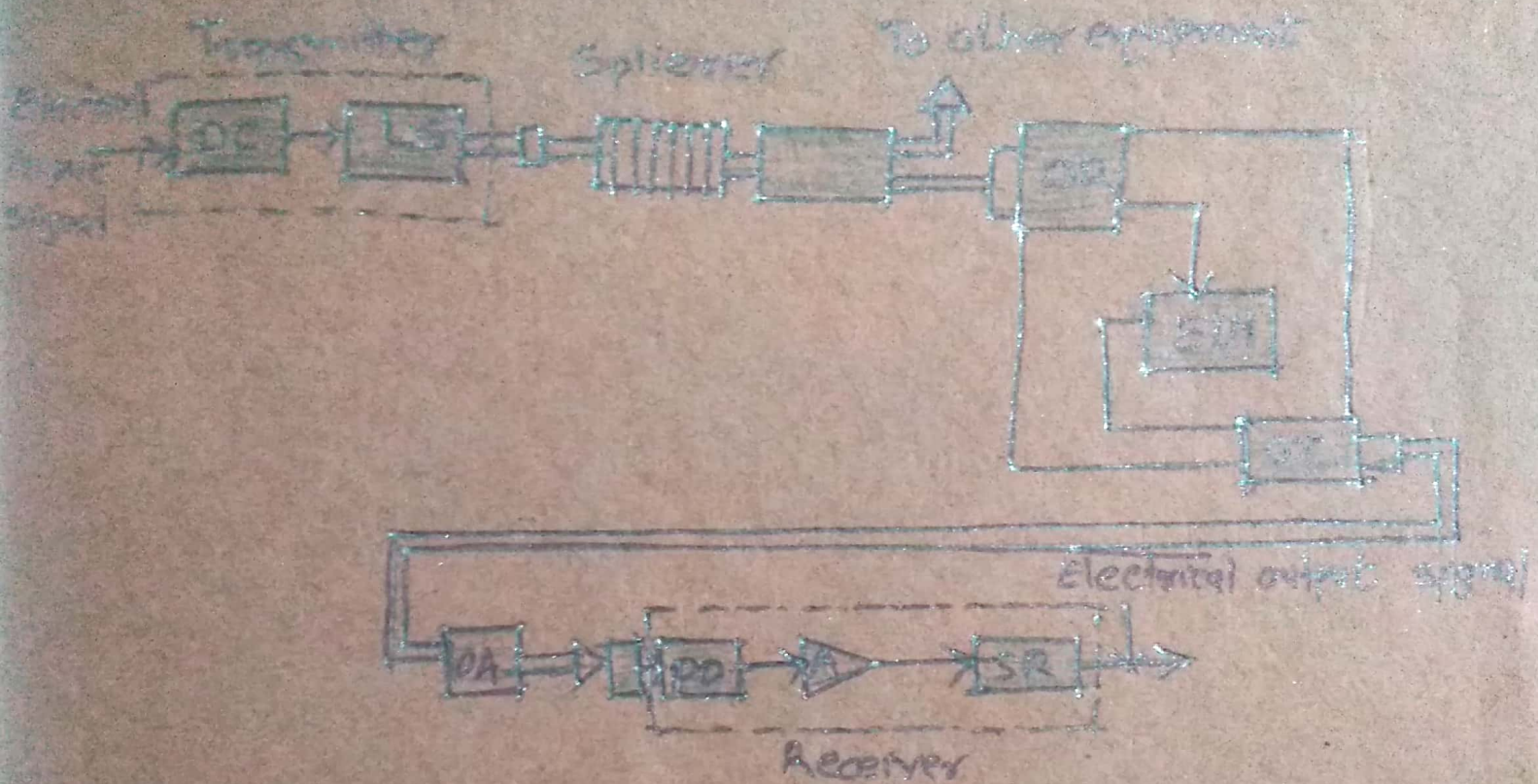
ii) Hologram reconstruction.

1) To see the reconstructed image, the hologram is illuminated by reference beam alone, maintaining the original alignment & orientation, this process is called as 'reconstruction'.

2) The developed photographic film (hologram) will have alternating transparent & opaque parts of very irregular shape. Thus, it will serve as a diffraction grating when illuminated by a light source.

3) The light from the hologram will be diffracted inward & outward. One set of diffracted rays will converge to form a real image while one set will diverge to form a virtual image.

4) Thus, the hologram can form real as well as virtual images. The geometry of construction can be changed, so as to give more emphasis on real or virtual image.



- DC - Drive Circuit
- LS - Light Source
- OA - Optical Receiver
- ELN - Electronics
- OA - Optical Amplifier
- PD - Photo Detector
- A - Amplifier
- SR - Signal Restorer