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Assignment No : 1

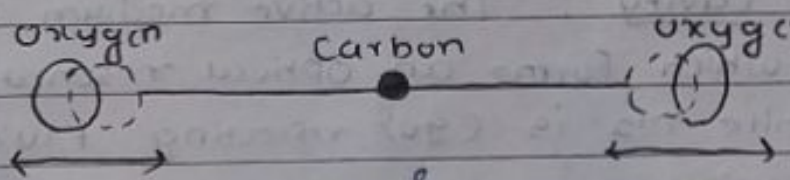
Q.1 Explain Principle, Construction & working of CO_2 Laser

→

Principle : The active medium is a gas mixture of CO_2, N_2 and He, The laser transition takes place between the vibrational states of CO_2 molecule.
CO_2 molecules exhibits 3 independent modes of vibration

1. Symmetric stretching mode
2. Asymmetric Stretching mode
3. Bending mode

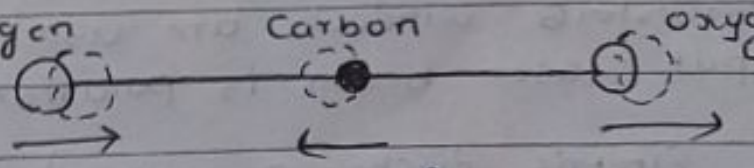
1.



S.S.M

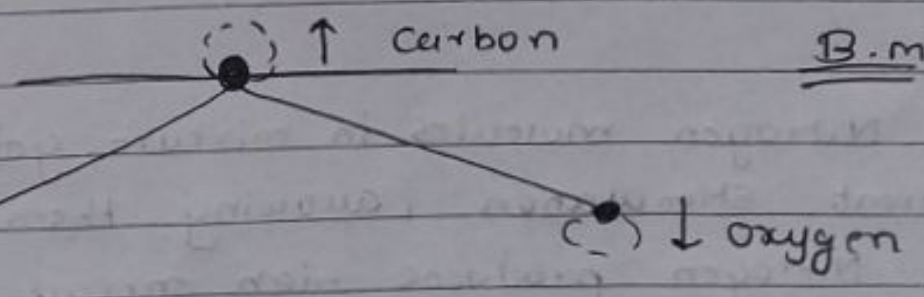
- Central carbon is at rest & both oxygen atoms vibrates along the axis of molecule approaching fixed central atom

2.



A.S.M

- Central carbon atom ~~vibr~~ & both oxygen atoms vibrates assymetrically i.e in opposite direction



B.M

Central carbon atom & oxygen atoms vibrates perpendicular to molecular axis.

Construction :

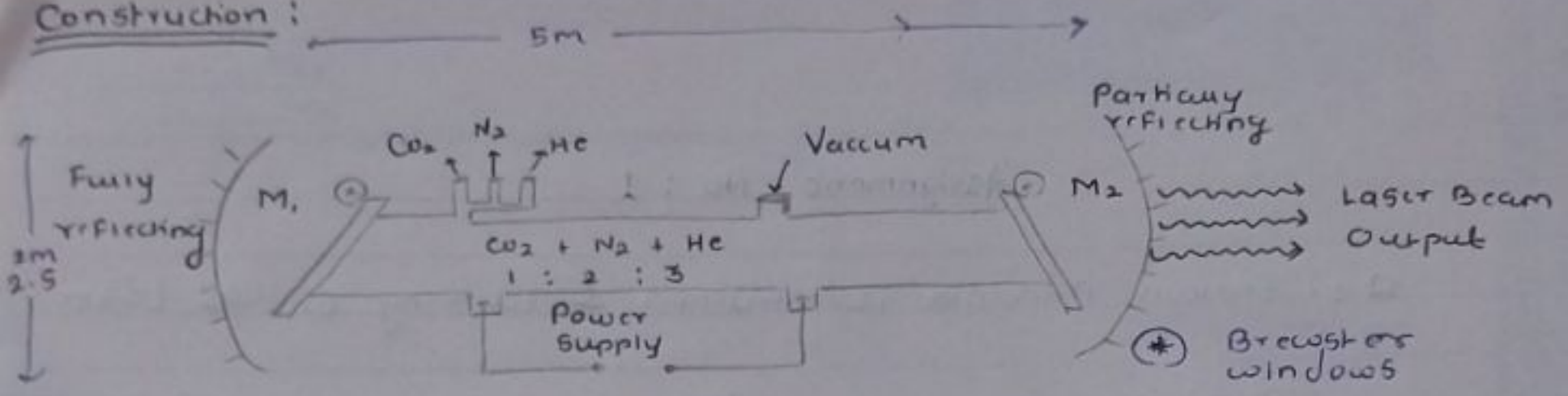


Fig: Schematic diagram of CO_2 Laser

1. Active medium : The active medium in CO_2 laser is mixture of CO_2, N_2 and He in the ratio 1:2:3 filled in quartz discharge tube of length 5m & diameter of 2.5 cm at a pressure of few mm of Hg, The active centres are CO_2 molecules as lasing action will be achived due to this molecules

2. Optical resonator cavity : The active medium is enclosed b/w a slit of concave mirrors which forms an optical resonator cavity, M_1 is 100% Reflecting while M_2 is (90% reflecting + 10% transmitting). Here we used external mirror cavity configuration,

The mirrors used in internal cavity configuration gets extended by gas discharge & have to be replaced. Brewsters windows are used at each end of discharge tube so that output laser beam is polarised.

3. pumping Source : Electric discharge method is used for pumping & acheving population inversion, The two electrode sealed inside the discharged tube are connected to a D.C power supply of few K.volts.

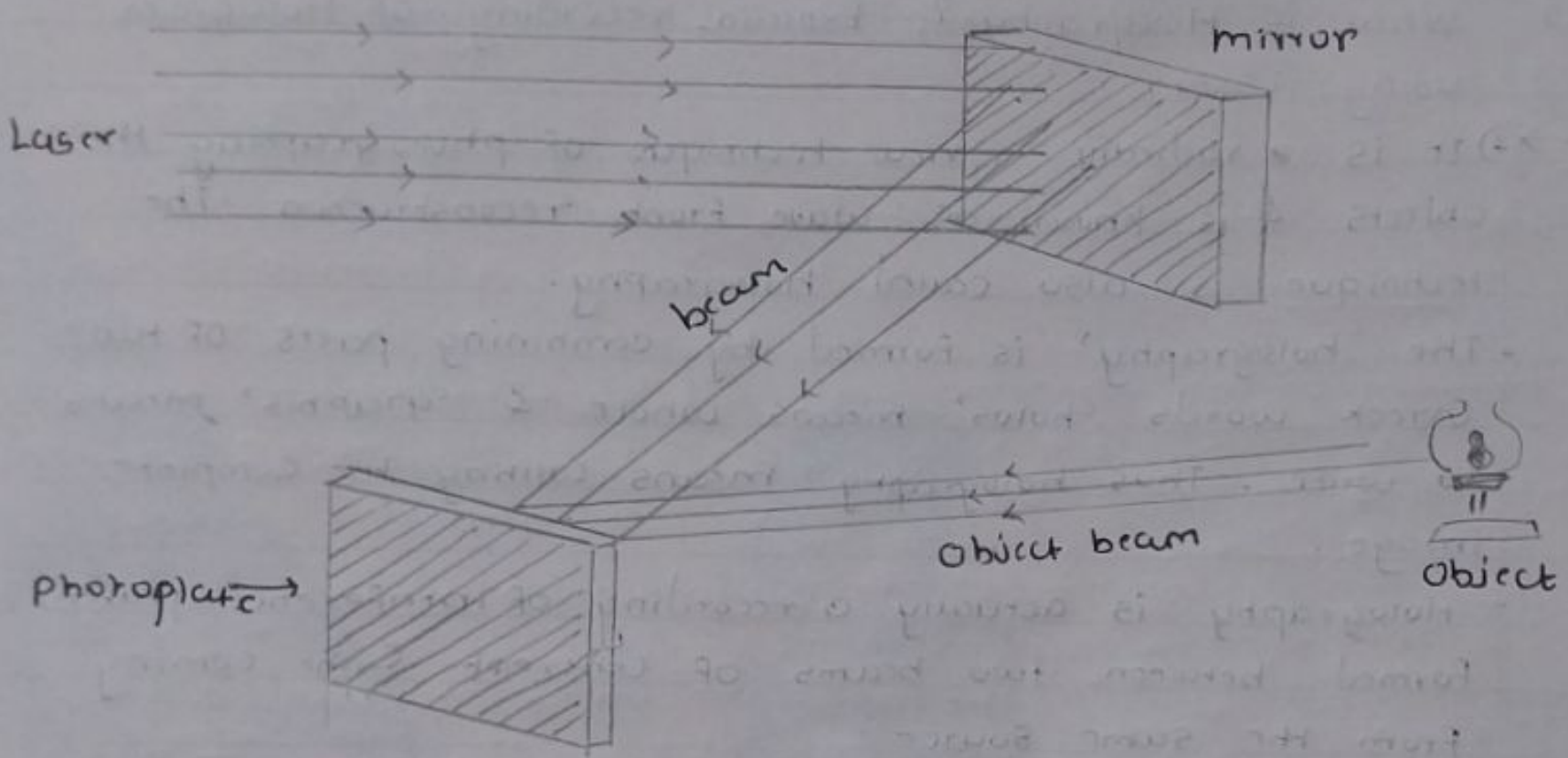
Working : Nitrogen molecules in mixture gains energy through electric current stimulation, allowing them to hold this state for longer. Nitrogen produces high energy vibrations & excitation of carbon dioxide molecules, acheving population inversion in lasers. Nitrogen atom lose excitement through photon release to produce light, when excited with extremely cold helium atoms, resulting in light.

Q.2 What is Holography? Explain recording of Hologram using Laser.

→ (i) It is a radially a new technique of photographing the objects & is known as wave front reconstruction. The technique is also called holography.

- The 'holography' is formed by combining parts of two Greek words 'holos' means whole & 'graphis' means to write. Thus holography means writing the complete image.
- Holography is actually a recording of interference pattern formed between two brams of coherent light coming from the same source

(ii) - In the opp-axis arrangement a broad laser is divided into two beams, namely a refrence beam and object bram by a beam splitter
- The refrence beam goes directly to the photographic plate. The second bram of light is directed onto the object to be photographed
- Each point of the object scatters the incident light and acts as the source of spherical waves.
- Part of the light, scattered by the object, travels towards the photographic plate. At the photographic plate the innumerable spherical waves from the object combine with the plane light wave from the refference beam.
- The sets of light waves are coherent because they are from the same laser. They interfere and form interference fringes on the plane of the photographic plate



(Generation of Hologram)

Q.3 What is population inversion? Explain why laser action cannot occur without population inversion between atomic levels?

→ i) ~~When~~ the number of atoms present at the excited state is greater than the no. of atoms present in the ground state is called population inversion ($N_2 > N_1$)

ii) For laser action, there should be more number of atoms in higher energy state, population inversion is the state in which the number of atoms in higher energy state is more than those in lower energy state

iii) In population inversion there is non-equilibrium condition which is necessary for stimulated emission to surpass absorption. without p.i, the number of atoms ready to emit photons is insufficient to sustain the lasing process

iv) population inversion allows for the amplification of light as the excess of of excited atoms can release their energy coherently with triggered leading to the characteristic intense and focused laser beam.

Q.4 Explain the following terms :

1) Critical angle
2) Acceptance cone
3) Numerical apperture

→

1) Critical angle :

- The incident angle for which angle of refraction is 90° is called as critical angle
Beyond this angle, total internal reflection occurs, and no light passes into the less dense medium.

It can be calculated using snells law, which relates the angle of incidence and refraction to the indices of refraction of two media

$$\sin(\theta_c) = \frac{n_2}{n_1}$$

θ_c = critical angle
n_2 = refractive index for denser medium
n_1 = refractive index for rarer medium

2) Acceptance cone :

- It refers to the range of angles at which light can enter an optical system, such as a lens or fiber optic. It defines the maximum angular width of incoming light that the system can effectively capture. A wider acceptance cone allows for more light collection, improving the system's performance and efficiency. This concept is essential in designing optical devices to ensure optical light gathering capabilities.

3) Numerical aperture (NA):

- It is a dimensionless number that characterizes the range of angles over which a lens or optical system can accept or emit light. It is crucial in determining the light gathering ability and resolution of optical systems, such as microscopes and fiber optics

It is mathematically defined as:

$NA = n \cdot \sin(\theta)$

n = refractive index of a medium

θ = half angle of maximum cone of light that can enter or exit lens.

Q.5 What is meant by acceptance angle for optical fiber? Show how it is related to numerical aperture.

→

The acceptance angle in optical fibers refers to maximum angle at which light can enter the fiber and still be guided through it effectively. It defines the cone of light that can be accepted by the fiber core and is crucial for efficient light transmission.

Relationship to Numerical aperture (NA):-

The acceptance angle (θ) is directly related to the numerical aperture (NA) of the optical fiber through the following relation:

$$NA = n_0 \cdot \sin(\theta) \quad ----(1)$$

where: NA = numerical aperture

n_0 = refractive index of medium surrounding fiber

θ = acceptance angle

From (1)

$$\sin(\theta) = \frac{NA}{n_0}$$

$$\therefore \theta = \sin^{-1}\left(\frac{NA}{n_0}\right)$$

That means that a higher numerical aperture allows for a larger acceptance angle, indicating that the fiber can accept light from a wide range of incident angles.

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Q 6 A fiber circle has an acceptance of angle of 30° and a core index of refraction of 1.4 calculate the Refractive Index of cladding.

→

$\theta = 30^\circ \quad n_1 = 1.4 \quad n_2 = ?$

$\theta = \frac{30^\circ \times \pi}{180^\circ 6} = \frac{\pi}{6}$ radian { converting ° to π°

as we know, $\sin(\theta) = \frac{n_2}{n_1}$

$n_2 = n_1 \cdot \sin(\theta)$

$\theta = \pi/6, \quad n_1 = 1.4$

$\frac{1}{2} = \frac{n_2}{1.4}$

$[n_2 = 0.7]$

Thus, refractive index of the cladding is

$\underline{\underline{0.7}}$

Q.7 In an optical fiber, the core material has refractive index 1.6 and refractive index of clad is 1.3. what is value of critical angle? also calculate the value angle of acceptance angle cone.

→

1. Critical angle $n_1 = 1.6$ & $n_2 = 1.3$

$$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

Substituting values,

$$\theta_c = \sin^{-1}\left(\frac{1.3}{1.6}\right)$$

$$\theta_c \approx \sin^{-1}(0.8125)$$

$$[\theta_c \approx 54.5^\circ]$$

2. Angle of acceptance cone

$$\sin(\theta_a) = \frac{n_2}{n_1}$$

Now substituting values,

$$\sin(\theta_a) = \frac{1.3}{1.6} = 0.8125$$

To find θ_a,

$$\theta_a = \sin^{-1}(0.8125) \approx 54.5^\circ$$

∴ Critical angle $(\theta_c) = 54.5^\circ$

angle of acceptance $(\theta_a) = 54.5^\circ$