Engineering Physics

(PHY1701)

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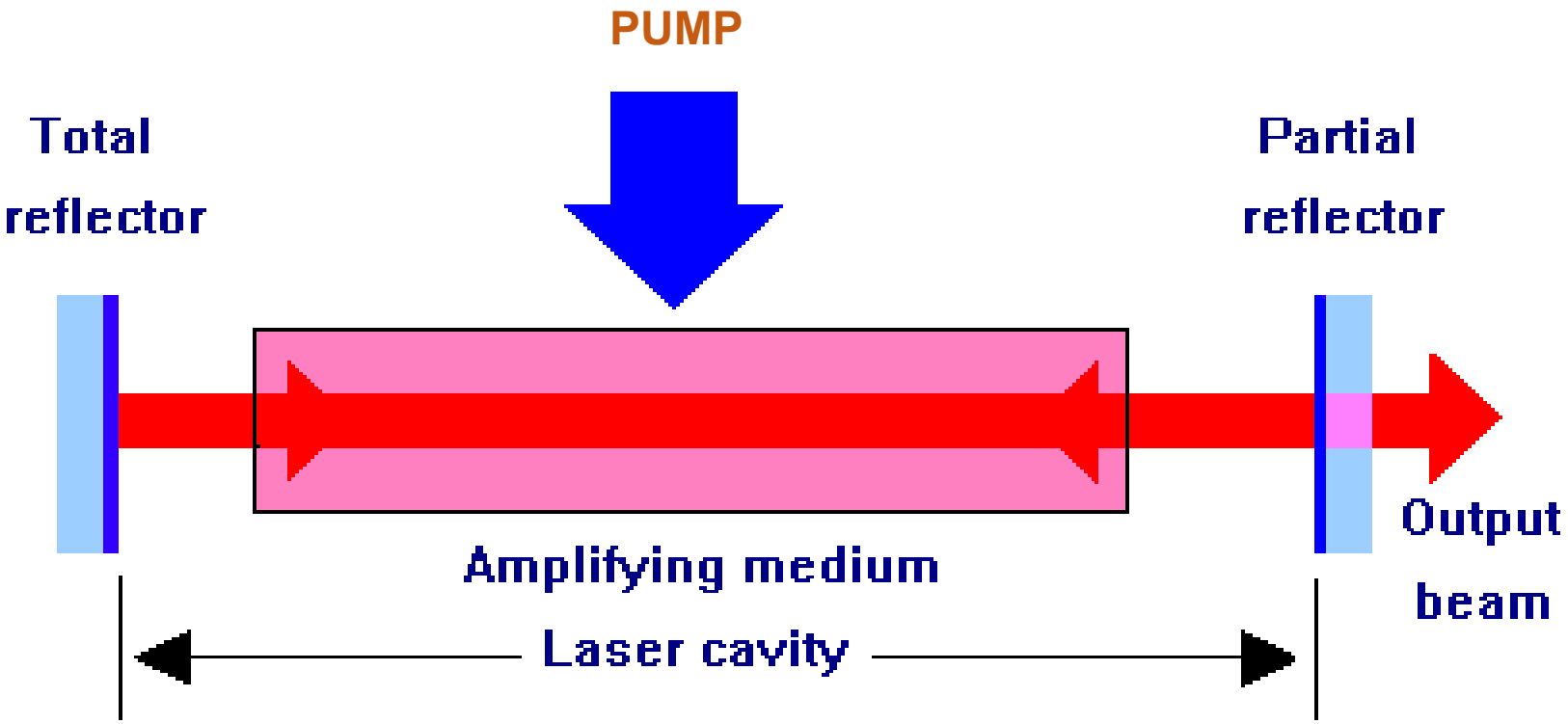
- **Nd-YAG, He-Ne, CO_2** and their engineering applications

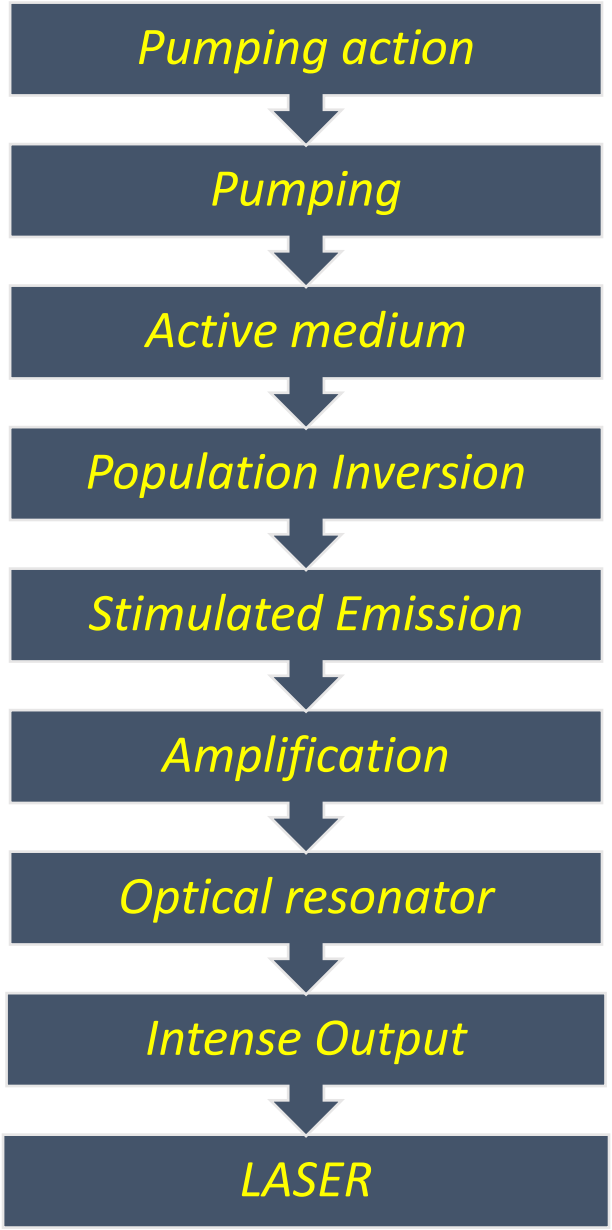
❖ William Silfvast, Laser Fundamentals, 2008, Cambridge University Press.

Components of Laser

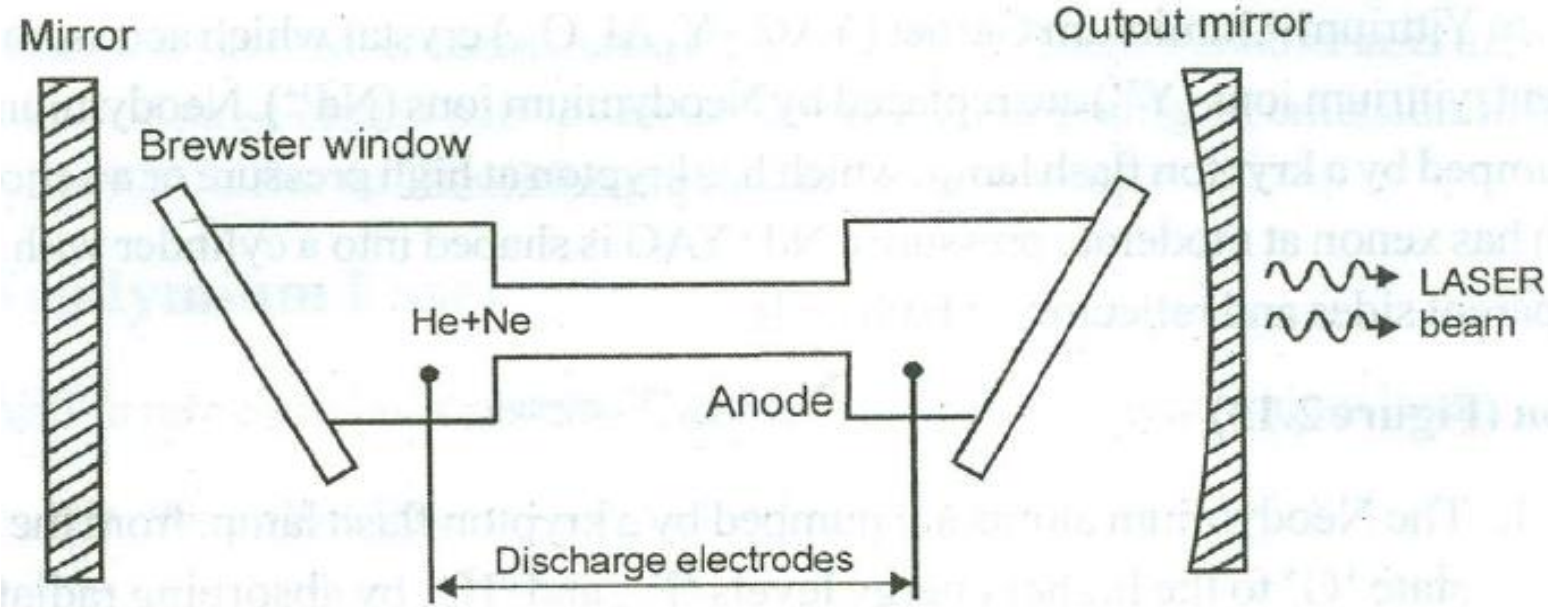


1. PUMP
2. OPTICAL RESONATOR / CAVITY
3. LASING MEDIUM

Flow Chart of Laser action



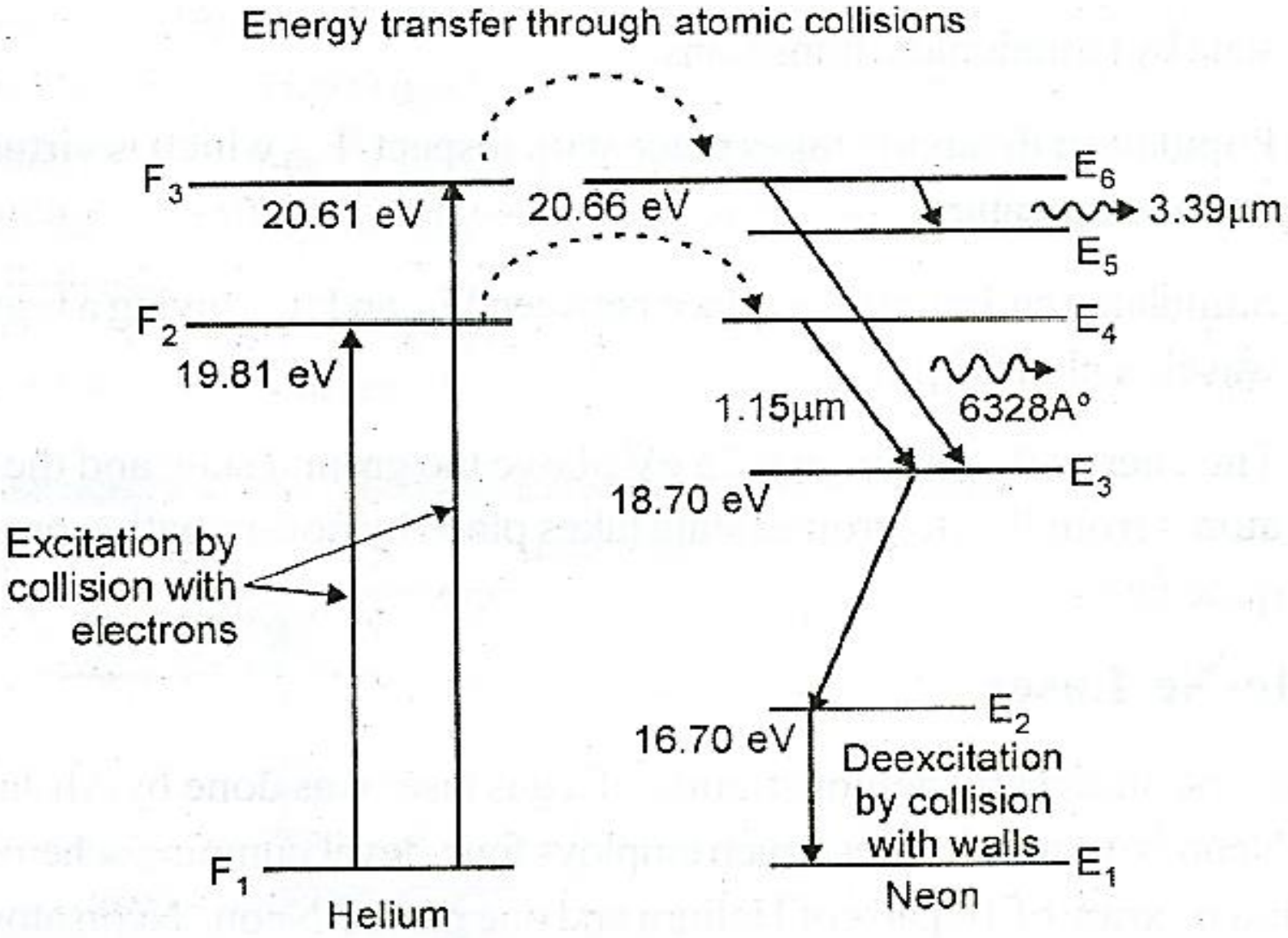
He-Ne Laser



Schematic diagram of He-Ne laser

CONSTRUCTION: The He-Ne laser consists of a long and narrow discharge tube having length about 50 cm and diameter 1.5 cm. The tube is filled with the mixture of He and Ne in the ratio 10:1 respectively. So majority atoms are Helium and minority atoms are Neon. Ne atoms act as active centers. Two mirrors M1 and M2 are mounted at the ends of the tube. The mirror M1 is completely silvered while the other M2 is partially silvered. The electrodes are connected to high voltage supply. The end windows of the tube are set at Brewster's angle to get polarized light at the output.

He-Ne Laser



Energy Level Diagram of He-Ne Laser

He-Ne Laser

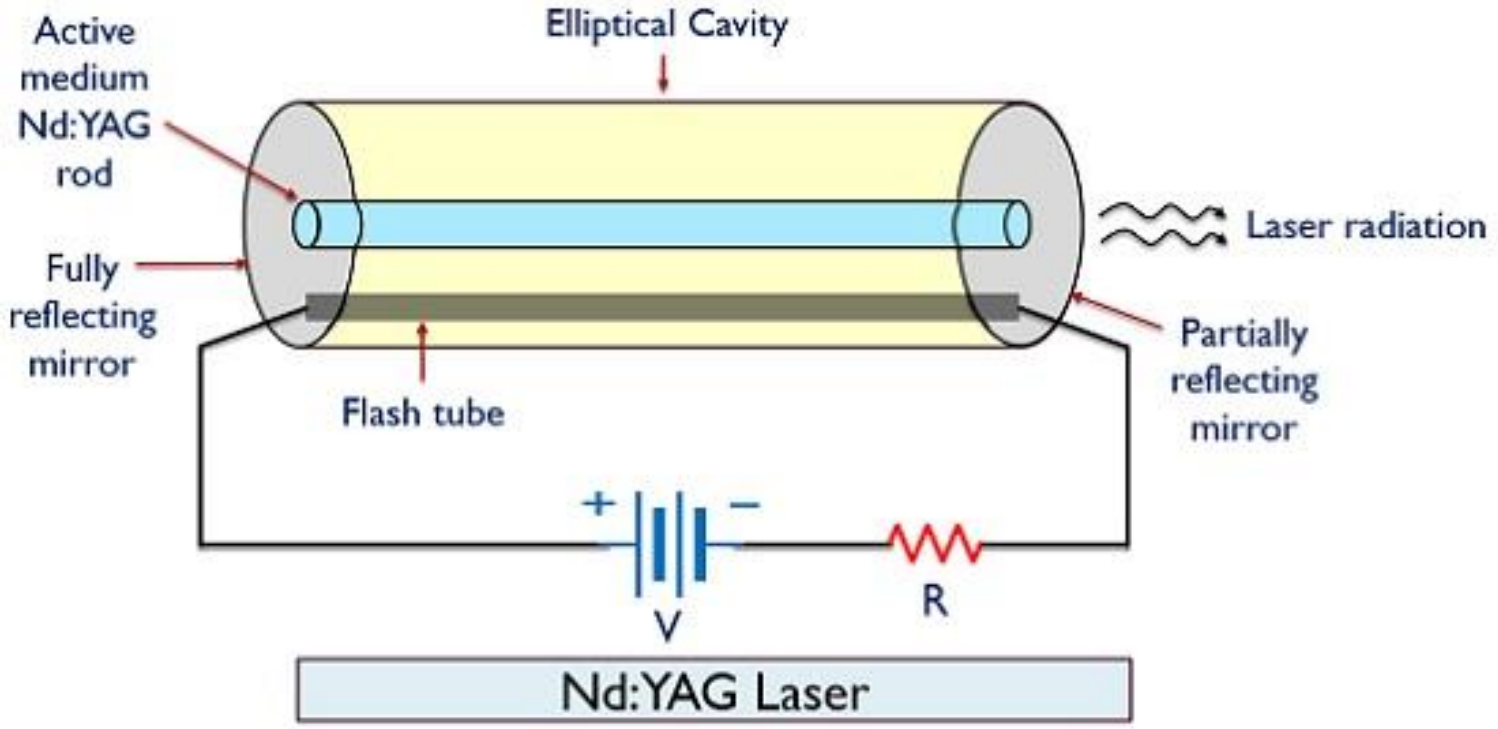
WORKING:

- When an electric discharge is passed through the gas, electrons are accelerated towards anode. These electrons collide with 'He' and 'Ne' atoms and excite them to higher energy levels.
- The 'He' atoms are more readily excitable than the neon atoms because they are lighter. Electrons excite He atoms to upper levels F_2 and F_3. These two levels are meta stable levels and the excited He atoms cannot return to the ground state.
- He atoms can return to the ground state by transferring their energy to neon atoms through collisions. As the energy exchange is continuous, the population inversion of Ne atoms in the excited states increases more and more.
- When an excited Ne atom passes from E_6 to E_5 and E_4 to E_3 spontaneously and emits a photon. This photon travels parallel to the axis of the tube and it reflected back and initiates stimulated photons.

He-Ne Laser

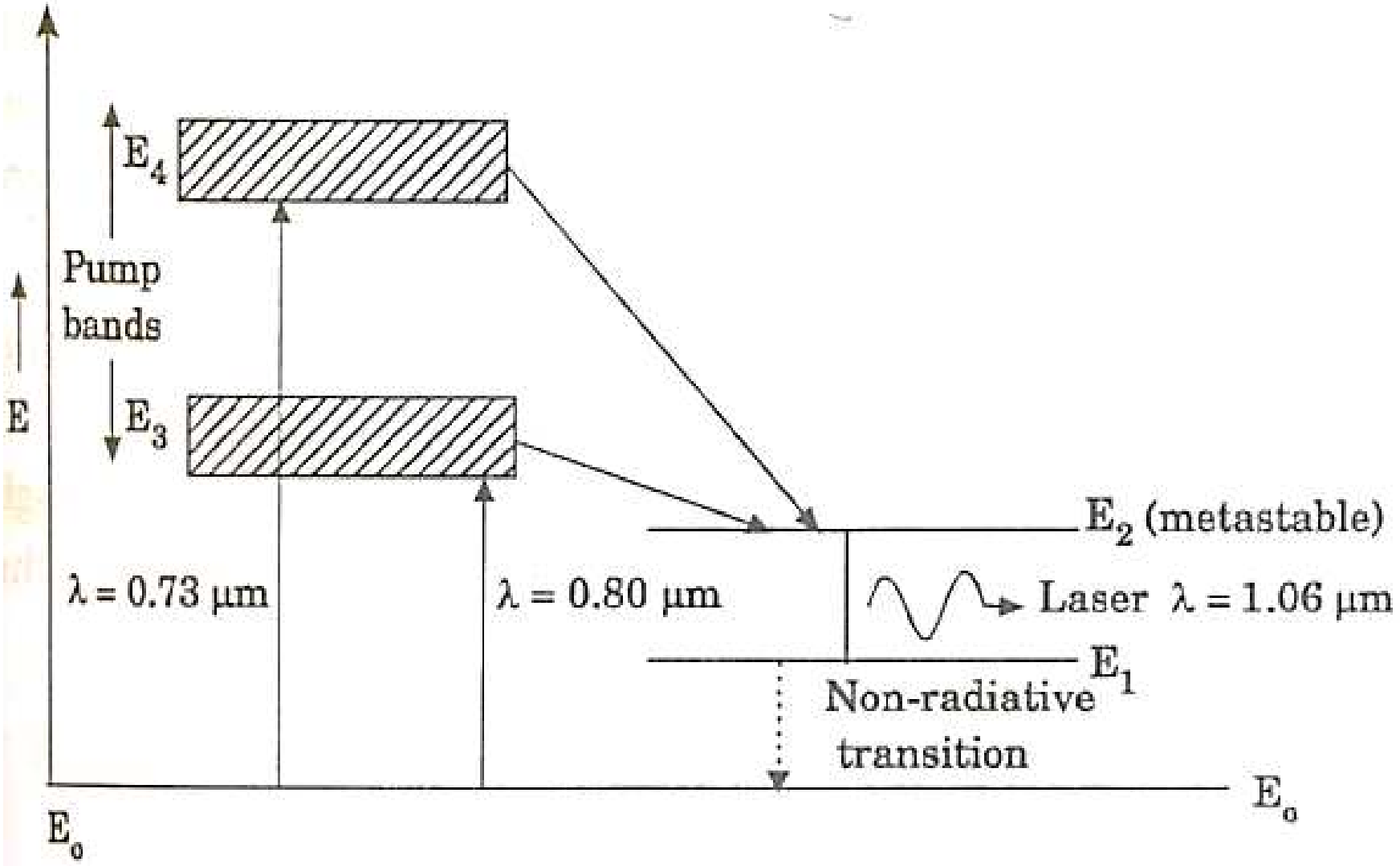
- These photons undergo multiple reflections between the mirrors, after getting sufficient intensity, a part of laser beam escapes through partially silvered mirror M_2.
- The level E_2 is metastable level. Therefore Ne atoms tend to accumulate at this level once again. Finally the Ne atoms come to ground level E_1 by the collision of walls of the tube. This transition is radiation less.
  - ✓ $E_6 \longrightarrow E_5$ transition: this transition generates a laser beam of wavelength 33,900 Å lies in infrared region
  - ✓ $E_6 \longrightarrow E_3$ transition: this transition generates a laser beam of wavelength 6328 Å lies in visible red region.
  - ✓ $E_4 \longrightarrow E_3$ transition: this transition generates a laser beam of wavelength 11,500 Å lies in infrared region.
- The He-Ne laser is made to oscillate at 6328 Å and by placing some optical absorbers in the path of light which absorb 33,900 Å and 11,500 Å wavelengths, releases 6328 Å only.

Nd:YAG Laser



CONSTRUCTION: A small amount of Yttrium ions (Y^{3+}) is replaced by Neodymium (Nd^{3+}) in the active element of Nd: YAG crystal. This active element is cut into a cylindrical rod. The ends of the cylindrical rod are highly polished and they are made optically flat and parallel. This cylindrical rod (laser rod) and a pumping source (flash tube) are placed inside a highly (reflecting) elliptical reflector cavity. The optical resonator is formed by using two external reflecting mirrors. One mirror (M1) is 100% reflecting while the other mirror (M2) is partially reflecting.

Nd:YAG Laser



Energy Level Diagram of Nd:YAG Laser

Nd:YAG Laser

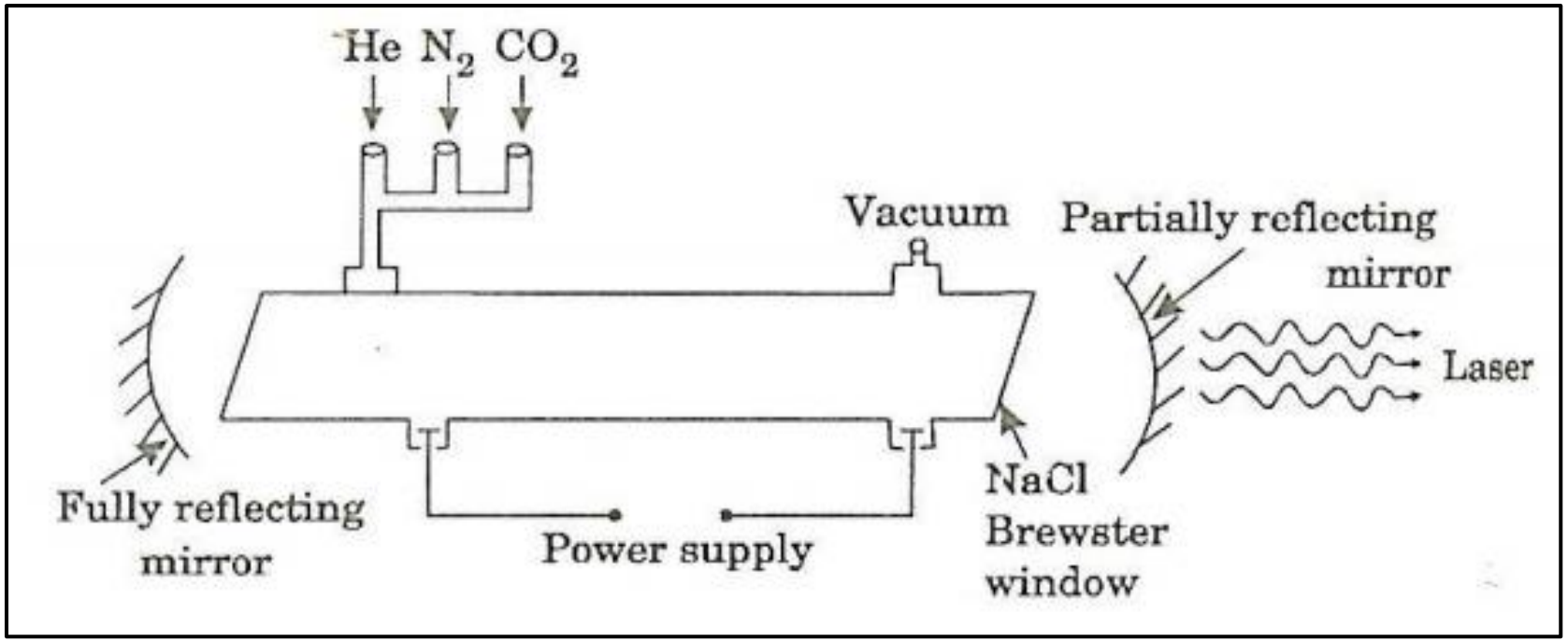
WORKING:

- When the krypton flash lamp is switched on, by the absorption of radiation of wavelength 0.73µm and 0.8µm, the Neodymium (Nd^{3+}) atoms are raised from E_0 to upper levels E_3 and E_4 (Pump bands).
- The Neodymium ions atoms make a transition from these energy levels E_2 by non-radiative transition. E_2 is a metastable state.
- The Neodymium ions are collected in the level E_2 and the population inversion is achieved between E_2 and E_1.
- An ion makes a spontaneous transition from E_2 to E_1, emitting a photon of energy hv. This emitted photon will trigger a chain of stimulated photons between E_2 and E_1. The photons thus generated travel back and forth between two mirrors and grow in strength. After some time, the photon number multiplies more rapidly.
- After enough strength is attained (condition for laser is satisfied), an intense laser light of wavelength 1.06µm is emitted through the partial reflector. It corresponds to the transition from E_2 to E_1.

Nd:YAG Laser : CHARACTERISTICS

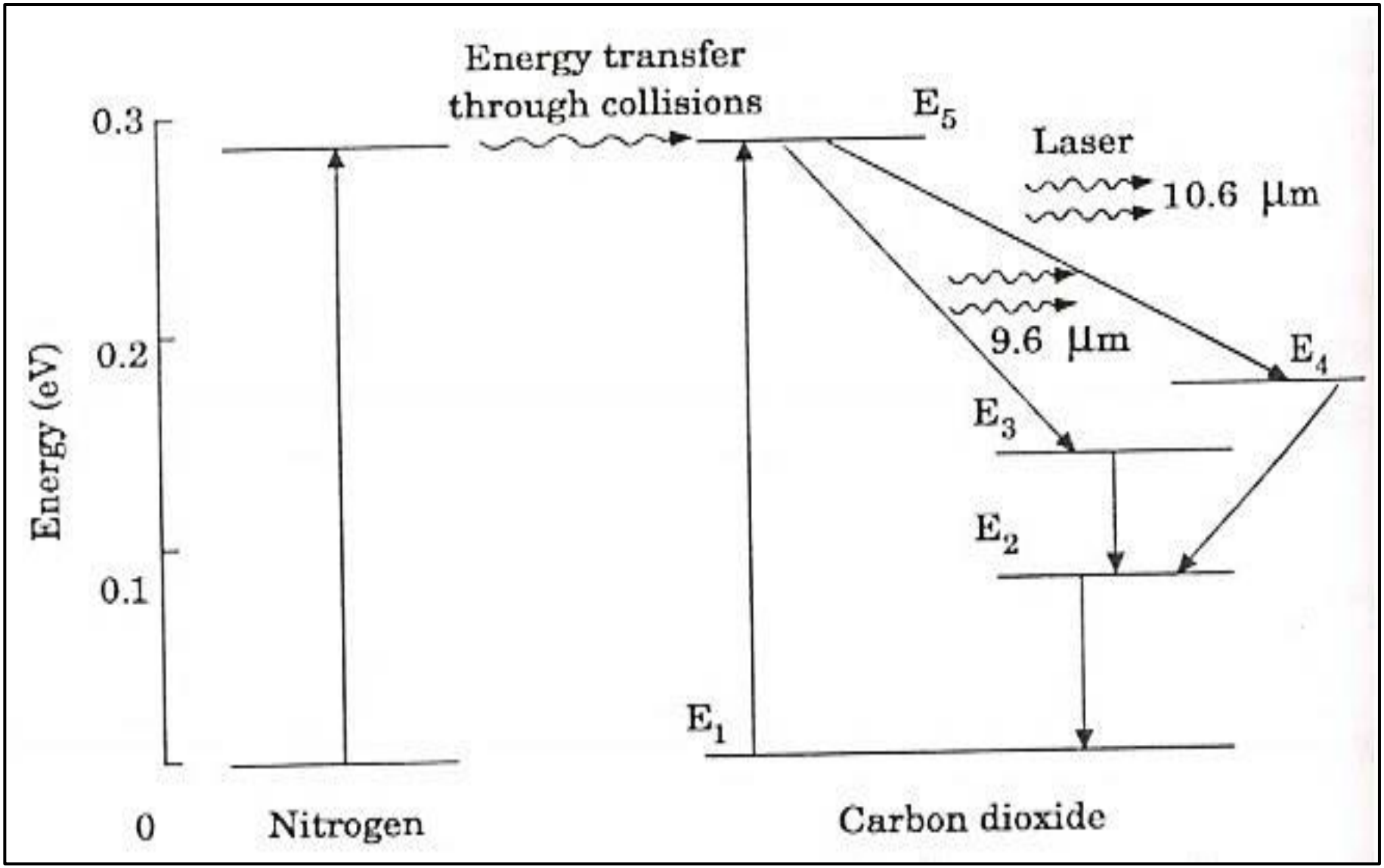
- Type: It is a four level solid state laser.
- Active medium: The active medium is Nd: YAG laser.
- Pumping method: Optical pumping is employed for pumping action.
- Pumping source: Xenon or Krypton flash tube
- Optical resonator: Two ends of Nd: YAG rod is polished with silver (one end is fully silvered and the other is partially silvered) are used as optical resonator.
- Power output: The power output is approximately 70 watt.
- Nature of output: Output is pulsed or continuous beam of light.
- Wavelength of the output: The wavelength of the output beam is 1.06μm (infra-red)
- **Advantages:**
  - It has high energy output.
  - It has very high repetition rate operation
  - It is much easy to achieve population inversion
- **Disadvantages:**
  - The electron energy level structure of Nd^{3+}in YAG is complicated.

CO_2 Laser



CONSTRUCTION: The discharge tube is filled with a mixture of carbondioxide, nitrogen and helium gases in 1:4:5 proportions. It consists of a quartz tube 5 m long and 2.5 cm in the diameter. This discharge tube is filled with gaseous mixture of CO_2 (active medium), helium and nitrogen with suitable partial pressures. The terminals of the discharge tubes are connected to a D.C power supply. The ends of the discharge tube are fitted with NaCl Brewster windows so that the laser light generated will be polarized. Two concave mirrors one fully reflecting and the other partially form an optical resonator.

CO_2 Laser



Energy Level Diagram of CO_2 Laser

CO_2 Laser

WORKING:

- When an electric discharge occurs in the gas, the electrons collide with nitrogen molecules and they are raised to excited states. This process is represented by the equation

$$N_2 + e^* = N_2^* + e$$

N_2 = Nitrogen molecule in ground state; e^* = electron with kinetic energy; N_2^* = nitrogen molecule in excited state; e = same electron with lesser energy.

- Now N_2 molecules in the excited state collide with CO_2 atoms in ground state and excite to higher electronic, vibrational and rotational levels. This process is represented by the equation

$$N_2^* + CO_2 = CO_2^* + N_2$$

N_2^* = Nitrogen molecule in excited state. CO_2 = Carbon dioxide atoms in ground state CO_2^* = Carbon dioxide atoms in excited state N_2 = Nitrogen molecule in ground state.

- Since the excited level of nitrogen is very close to the E_5 level of CO_2 atom, population in E_5 level increases.
- As soon as population inversion is reached, any of the spontaneously emitted photon will trigger laser action in the tube. There are two types of laser transition possible.

CO_2 Laser

- ✓ $E_5 \longrightarrow E_4$ transition: This will produce a laser beam of wavelength 10.6µm
- ✓ $E_5 \longrightarrow E_3$ transition: This transition will produce a laser beam of wavelength 9.6µm. Normally 10.6µm transition is more intense than 9.6µm transition. The power output from this laser is 10kW.

Characteristics:

- Type: It is a molecular gas laser.
- Active medium: A mixture of CO_2 , N_2 and helium or water vapour is used as active medium
- Pumping method: Electrical discharge method – pumping action
- Optical resonator: Two concave mirrors form a resonant cavity
- Power output: The power output from this laser is about 10kW.
- Nature of output: The nature of output may be continuous wave or pulsed wave.
- Wavelength of output: The wavelength of output is 0.6µm and 10.6µm.

CO_2 Laser

Advantages:

1. The construction of CO_2 laser is simple
2. The output of this laser is continuous.
3. It has high efficiency
4. It has very high output power.
5. The output power can be increased by extending the length of the gas tube.

Disadvantages:

1. The contamination of oxygen by carbon monoxide will have some effect on laser action
2. The operating temperature plays an important role in determining the output power of laser.
3. The corrosion may occur at the reflecting plates.
4. Accidental exposure may damage our eyes, since it is invisible (infra red region) to our eyes.