LASER
&
IT'S APPLICATIONS

(CO-4 Part-III)

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Nd YAG Laser

- Nd: YAG laser is a ***four-level laser system***, which means that the four energy levels are involved in laser action. These lasers operate in both pulsed and continuous mode.
- It is a ***solid state laser*** in which Nd: YAG crystal is used as a laser medium.
- Nd: YAG stands for ***Neodymium*** (Nd^{+3}) doped ***Yttrium Aluminum Garnet*** ($Y_3Al_5O_{12}$).
- It generates laser light commonly in the near ***IR region*** (infrared region).
- Nd^{+3} ions are the ***active centers***.

Construction of Nd:YAG Laser

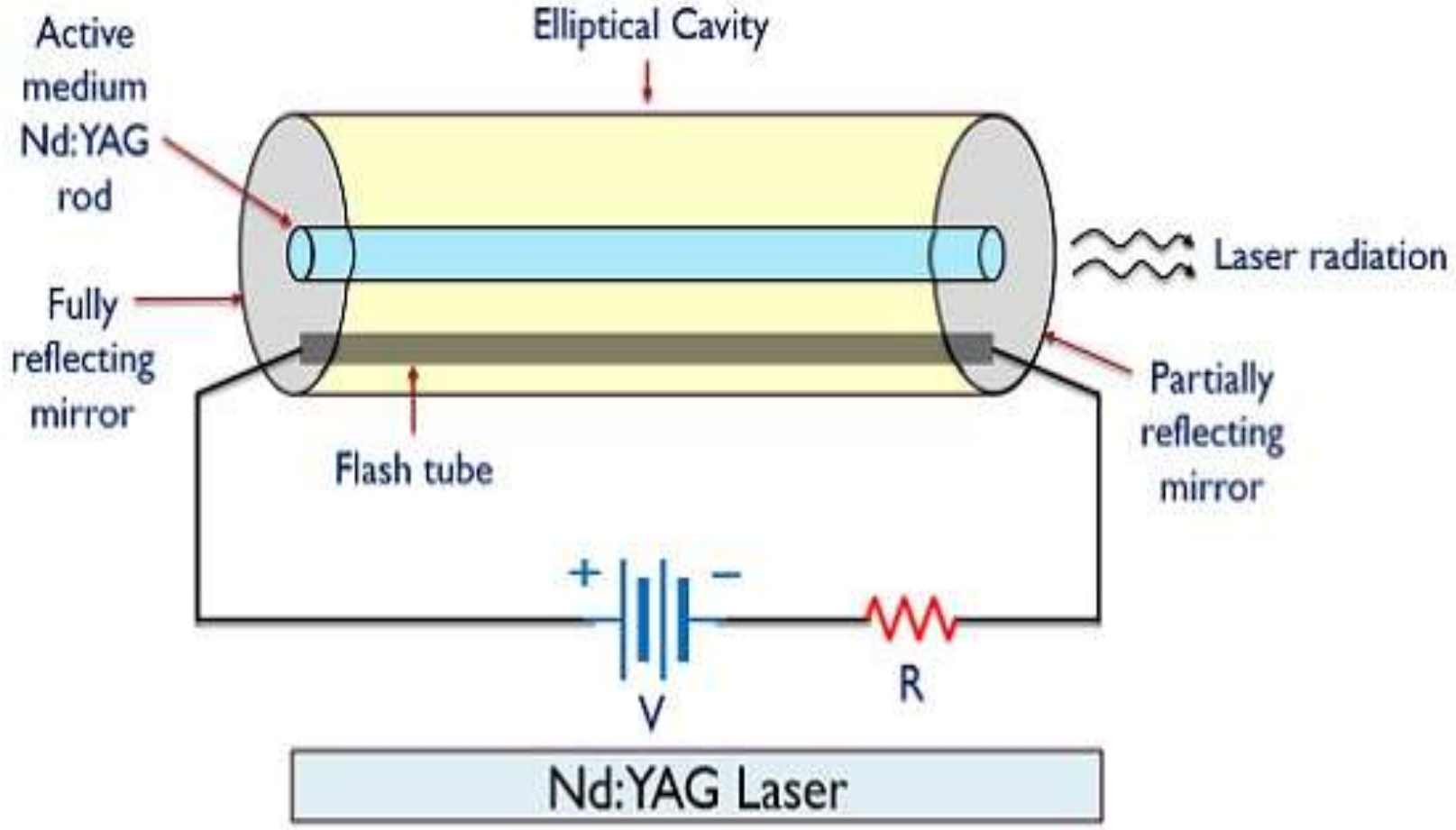


Figure.1*

- Nd:YAG laser consists of three important elements: an energy source, active medium, and optical resonator .
- The *energy source* supplies energy to the active medium to raise the system in excited state. In this laser, Krypton (Kr) arc lamp used as energy source.
- The active medium is made up of a synthetic crystalline material Yttrium Aluminum Garnet (YAG) doped with neodymium (Nd).
- The Nd: YAG crystal is placed between two mirrors. one mirror is fully silvered whereas, another mirror is partially silvered.

Working of Nd YAG laser

- The energy level E_1 is known as ground state, E_2 is the next higher energy state, E_3 is the metastable state and E_4 is the pump state or excited state.
- When flashtube supplies light energy to the active medium (Nd:YAG crystal), neodymium ions gains enough energy to the electron and moves to the pump state or higher energy state E_4.
- The lifetime of higher energy state E_4 is very small (10^{-8} sec). After this short period, the electrons will fall into the next lower energy state or metastable state E_3 by releasing non-radiation energy.

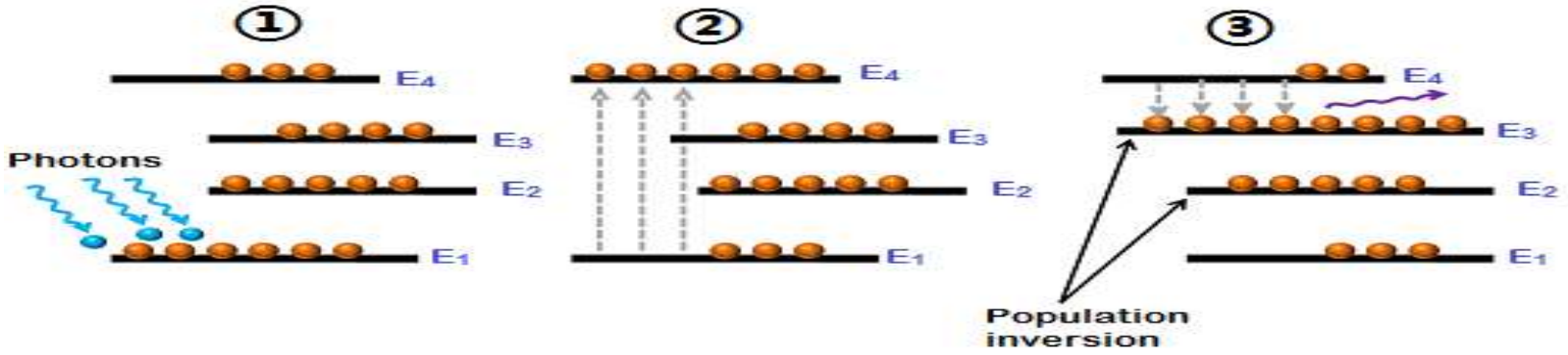


Figure.2*

- The lifetime of metastable state E_3 is high as compared to the lifetime of pump state E_4. This results in an increase in the no of electrons in the metastable E_3 and hence population inversion is achieved.
- After some period, the electrons in the metastable state E_3 will fall into the next lower energy state E_2 by releasing photons. The emission of photons in this manner is called spontaneous emission.

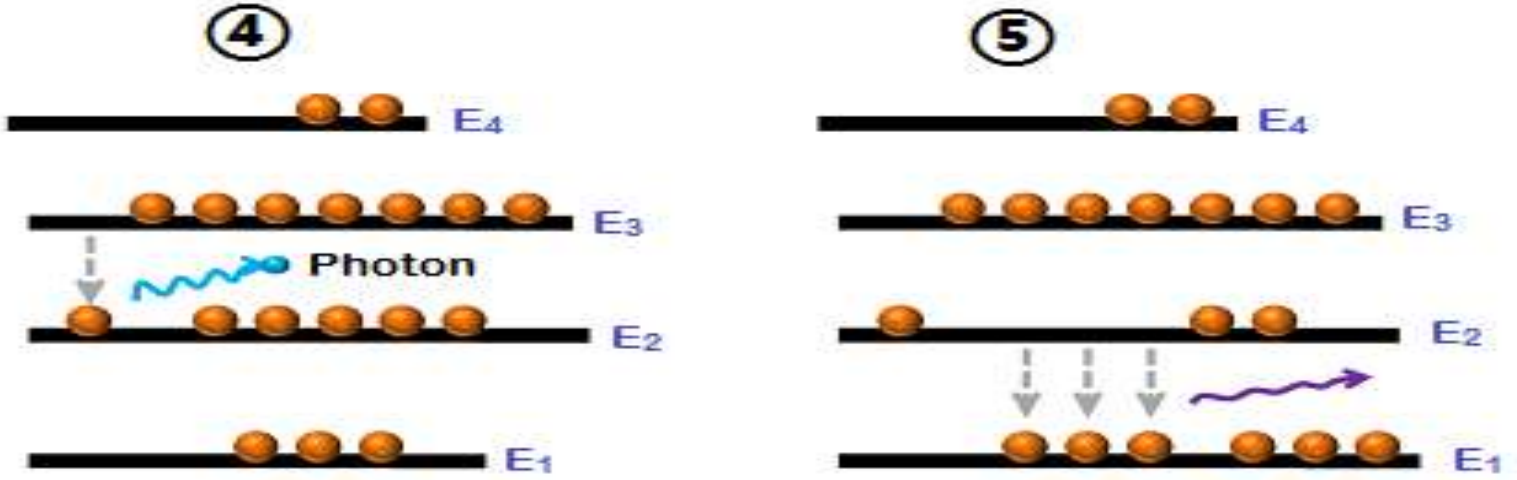


Figure.3*

- When photon emitted due to self emission is interacted with the other metastable state electron, it stimulates that electron and makes it fall into the lower energy state by releasing the photon. As a result, two photons are released. The emission of photons in this manner is called stimulated emission of radiation.

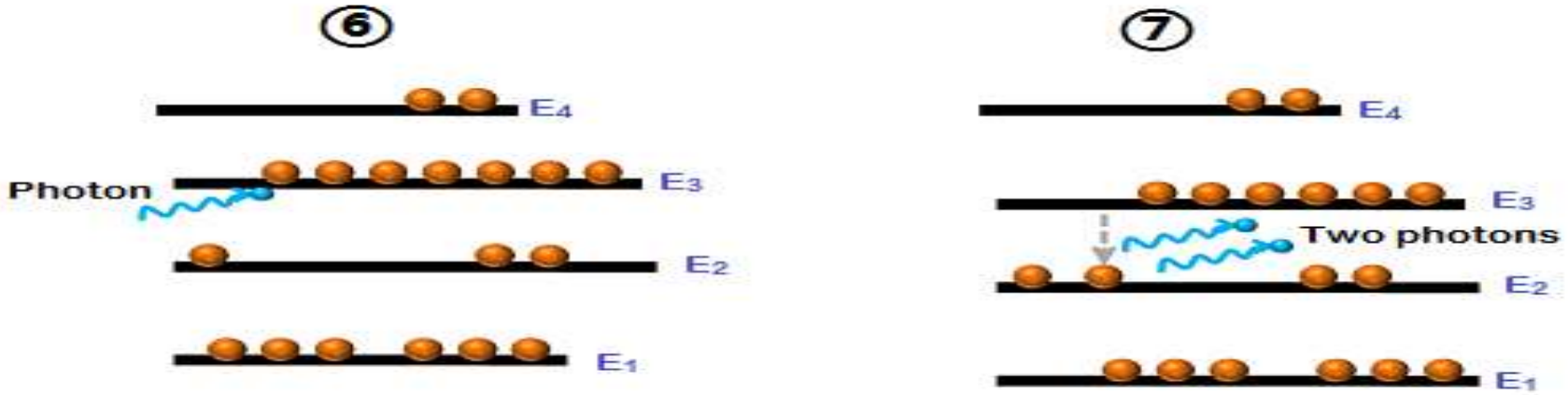


Figure.4*

- When these two photons again interacted with the metastable state electrons, four photons are released. Likewise, millions of photons are emitted. Thus, optical gain is achieved. Thereby generating a coherent laser beam of 10,640Å.

Advantages of Nd:YAG laser

- Nd:YAG laser offers high gain.
- Low power consumption.
- The efficiency is very high as compared to the ruby laser.
- It has good thermal & mechanical properties.
- It is much easy to achieve population inversion.

Applications of Nd:YAG laser

- Nd:YAG lasers are used in laser designators and laser rangefinders.
- It is used for cutting and welding steel.
- It finds many medical applications such as endoscopy, urology, neurosurgery, ENT, gynecology, dermatology, dental surgery and general surgery & used to remove skin cancers.

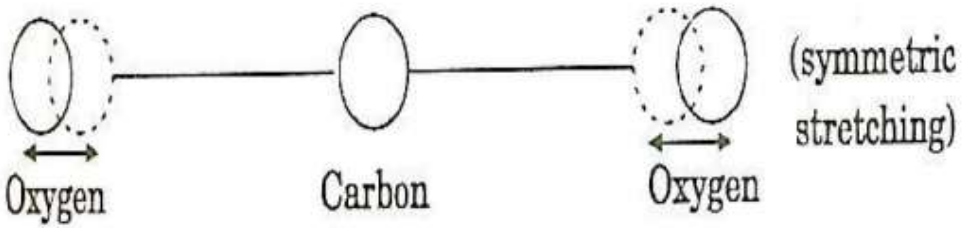
Carbon Dioxide Laser

- CO_2 was the first ***molecular gas laser*** developed by American scientist Prof. C. K. N. Pillai.
- It is a ***four level gas laser*** and it operates at 10.6 μm in the far ***IR region***. It is a very efficient laser.
- Laser action is achieved by transitions between ***vibrational*** and ***rotational levels*** of molecules.
- Its output of this laser is ***continuous***.
- The ***active medium*** is a gas mixture of CO_2, N_2 and He.

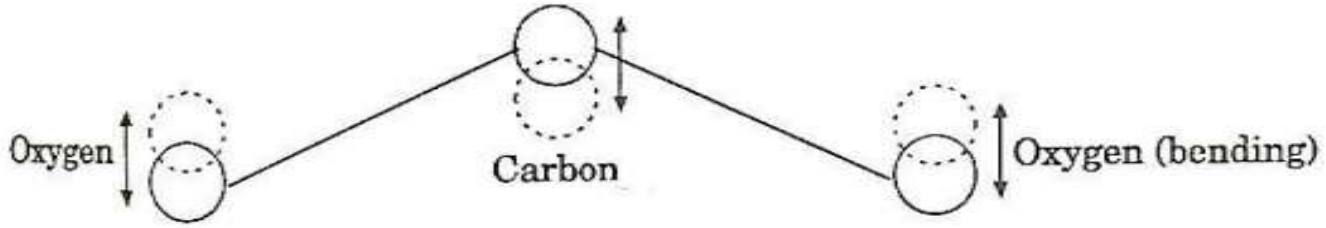
Energy states of CO_2 molecules

- A CO_2 molecule has a carbon atom at the center with two oxygen atoms attached, one at both sides. CO_2 molecule exhibits three independent modes of vibrations. They are

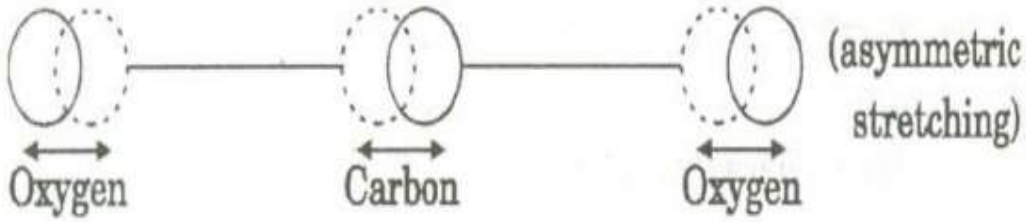
(a)Symmetric stretching mode:- In this mode of vibration, carbon atoms are at rest and both oxygen atoms vibrate simultaneously along the axis of the molecule departing or approaching the fixed carbon atoms.



(b)Bending mode:- In this mode of vibration, oxygen atoms and carbon atoms vibrate perpendicular to molecular axis.



(c)Asymmetric stretching mode:- In this mode of vibration, oxygen atoms and carbon atoms vibrate asymmetrically, i.e., oxygen atoms move in one direction while carbon atoms in the other direction.



Construction of CO_2 Laser

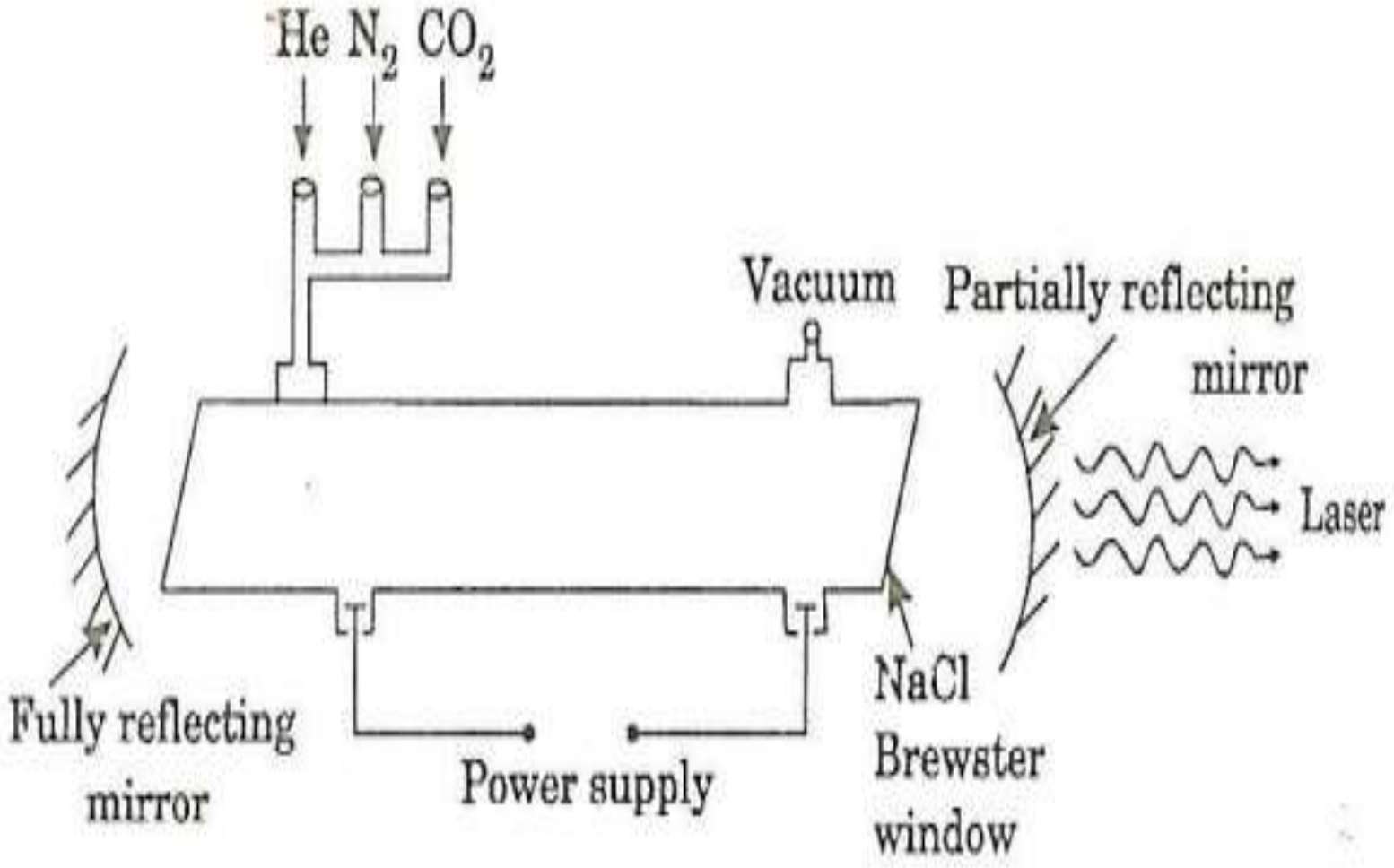


Figure.5*

- It consists of a quartz tube around 5 m long and 2.0 cm in the diameter. This is filled with gaseous mixture of CO_2, helium and nitrogen in the ratio 1: 2: 3 with suitable partial pressures.
- The terminals of the discharge tubes are connected to a DC power supply.
- Two concave mirrors one fully reflecting and the other partially form an optical resonator.

Working of CO_2 Laser

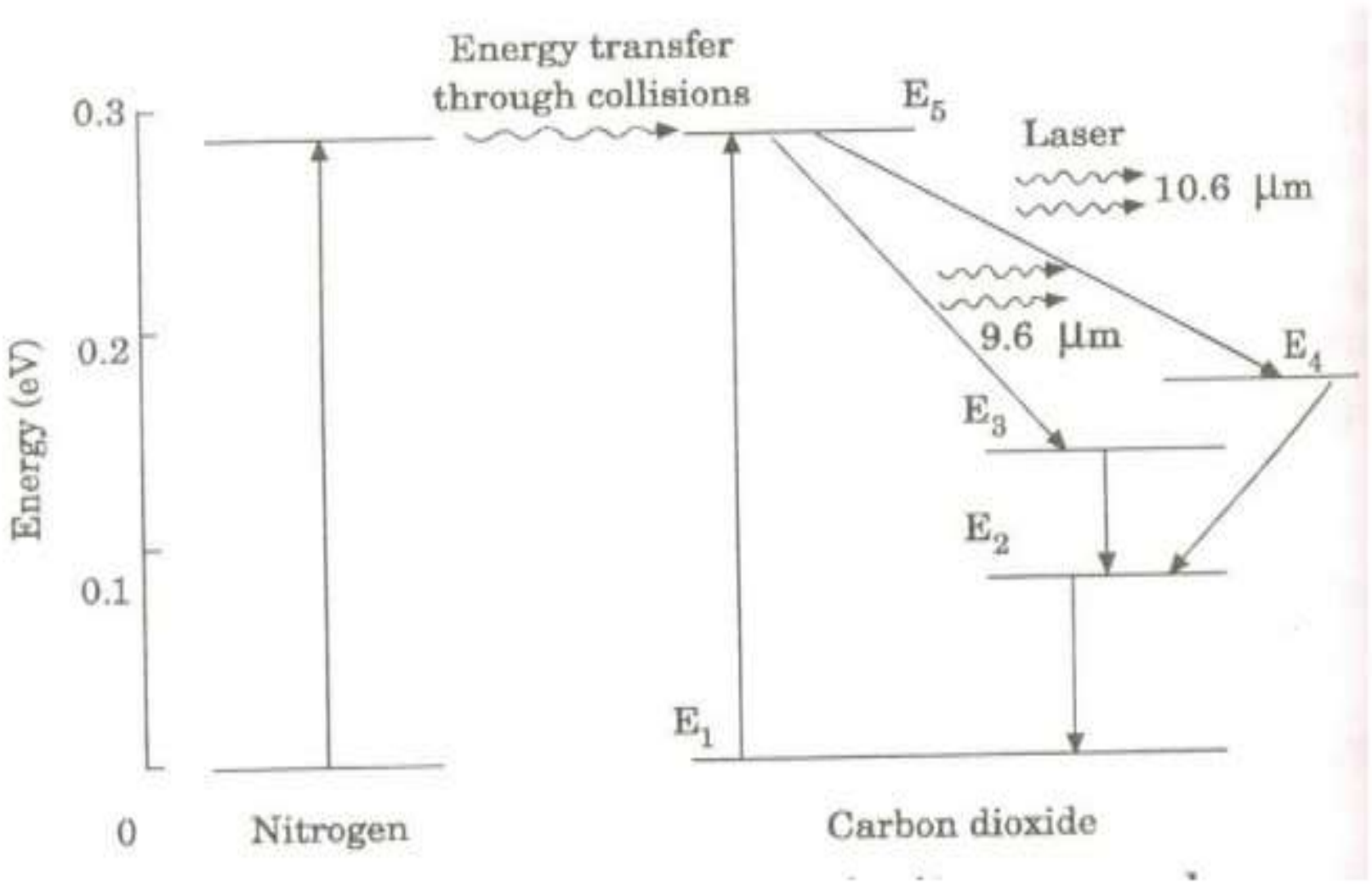


Figure.6*

- ***Electrical discharge*** method is used for Pumping action.
- When an electric discharge occurs in the gas, the electrons collide with nitrogen molecules and they are raised to excited states.
- 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.
- Since the excited level of nitrogen is very close to the E_5 level of CO_2 atom, population of atoms in E_5 level increases.

- As soon as population inversion is reached, any of the self emitted photon will trigger laser action in the tube. There are two types of laser transition possible.

Transition E_5 to E_4 : This will produce a laser beam of wavelength 10.6μm.

Transition E_5 to E_3 :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.

Advantages of CO_2 Laser

- It has high efficiency & very high output power.
- The output of this laser is continuous.
- The output power can be increased by extending the length of the gas tube.

Disadvantages of CO_2 Laser

- The corrosion may occur at the reflecting plates.
- Accidental exposure may damage our eyes, since it is invisible (infra red region) to our eyes.
- The contamination of oxygen by carbon monoxide will have some effect on laser action.

Applications of CO_2 Laser

- High power CO_2 laser used in material processing, welding, drilling, cutting soldering etc.
- It is used for remote sensing.
- It is used for treatment of liver and lung diseases.
- It is mostly used in neuro surgery, microsurgery and bloodless operations.

References:-
Figure1-4* https://www.physics-and-radio-electronics.com/physics/laser/ndyaglaser.html
Figure5-6* *A textbook of Engineering Physics by Navneet Gupta & S. K. Tiwari*