UNIT – II LASER AND FIBER OPTICS

TOPIC – IV: CO2 Laser

Carbon Dioxide (CO_2) Laser

It was the first molecular laser developed by an Indian born American Scientist Prof. C.K.N.Patel.

It is a very efficient laser. It is a four - level molecular gas laser and operates at 10.6 μm in far IR region.

Energy states of CO_2 molecules

A carbon dioxide molecule has a central carbon atom with two oxygen atoms attached, one at both sides. Fig 13.3. Such a molecule exhibit **three independent modes of vibrations.** The energy states of the CO_2 molecule arise due to its vibrations .

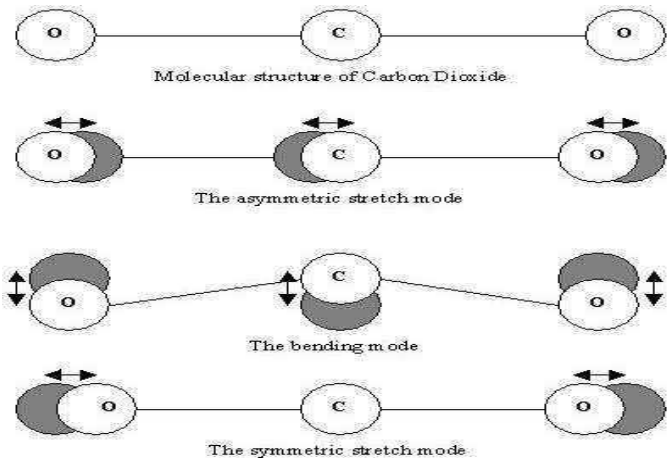

Fig .12 Different modes of vibrations of CO_2 molecule

(i). Symmetric stretching mode

In this mode of vibration, the carbon atom is at rest in its position and both oxygen atoms vibrate simultaneously along the axis of the molecule departing or approaching the fixed carbon atom Fig 12.

(ii). Bending mode

In this mode of vibration, the oxygen atoms and carbon atom vibrate perpendicular to

the molecular axis Fig 12.

(iii). Asymmetric stretching mode

In this mode of vibration, the oxygen atoms and carbon atom vibrate asymmetrically, i.e., oxygen atoms move in one direction while carbon atom moves in the opposite direction Fig 12.

Principle

The active medium in CO_2 laser is CO_2 gas. Laser transition takes place between the vibrational states of CO_2 molecules.

Construction

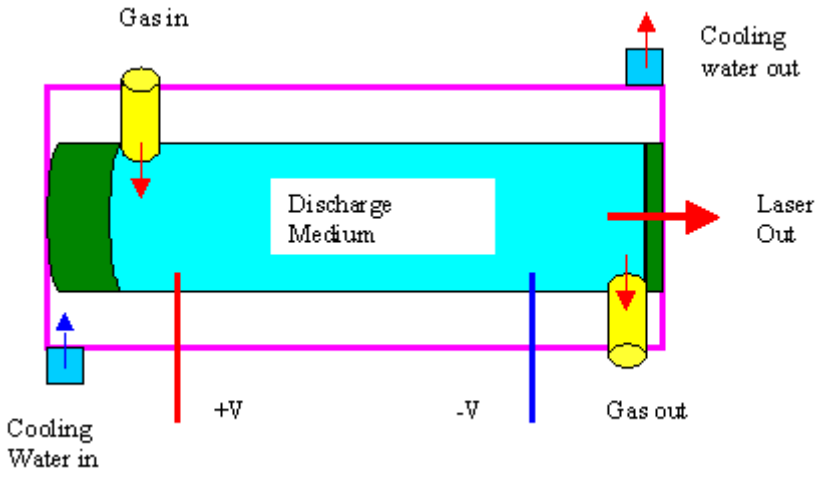

Fig 13 Schematic diagram of CO_2 laser

The CO_2 laser in Fig 13. consists of a quartz discharge tube 4m long and 2.4cm in diametre. The discharge tube is filled with gaseous mixture of CO_2 (active medium), helium and nitrogen with suitable partial pressures.

The terminals of the discharge tube 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 would be polarized.

The concave mirrors are provided, one completely reflecting and the other partially reflecting. They form the optical resonator.

Working

Fig 14.shows the vibrational level of the electronic ground state of CO_2 and N_2 molecules.

When an electrical discharge is passed through the gas, the electrons collide with nitrogen molecules and are raised to excited states. This is represented by

$N_2 + e \longrightarrow N^*_2 + e_1$

N_2 is the nitrogen molecule in ground state

e is the electron with kinetic energy

N^*_2 is the nitrogen molecule in excited state.

e_1 is the same electron with lesser energy.

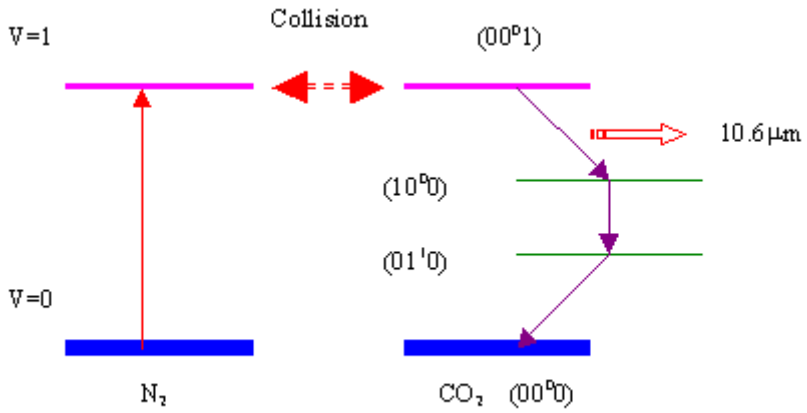

Fig 14 Energy level diagram of CO_2 laser

Subsequently N_2 molecules in excited state collide with CO_2 atoms in ground state and excite them to higher electronic, vibrational and rotational levels.

$N^*_2 + CO_2 \longrightarrow CO^*_2 + N_2$

N^*_2 is the nitrogen molecule in excited state

CO_2 is carbon dioxide atoms in ground state

CO^*_2 is carbon dioxide atoms in excited state.

N_2 is the nitrogen molecule in ground state.

Since the excited level of nitrogen is very close to the 001 level of CO_2 atom, the population in 001 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.

001 - 100 transition : This transition would produce a laser beam of wavelength 10.6 μm.

001 - E_3 transition : This transition would produce a laser beam of wavelength 9.6 μm.

Normally 10.6 μm transition is more intense than 9.6 μm transition. The power output expected from this laser is 10 kW.

The helium gas is used in conducting the heat generated in the central region of the discharge tube to the walls of the discharge tube.

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 is employed for the pumping action.
- **Optical Resonator :** Two concave mirrors form the resonant cavity..
- **Power Output :** The Power output expected from this laser is about 10 kW.
- **Nature of Output :** The nature of output may be continuous wave or pulsed wave.
- **Wavelength of output :** The wavelength of the output beam is 9.6 μm and 10.6 m (96000 Å and 10600 Å).

Advantages

- The construction of CO_2 laser is simple.
- .The output of this laser is continuous.
- It has extremely high efficiency.
- It has very high output power.
- The output power can be increased by extending the length of gas tube.

Disadvantages

- The contamination of oxygen by carbon monoxide will have some effect on laser action.
- Operating temperature plays an important role in determining the output power of laser.
- Corrosion may occur in the reflecting plates.
- Accidental exposure may damage our eyes, since it is invisible to our eyes.

Applications

- High - power CO_2 laser finds application in materials processing, welding, drilling, cutting, soldering, etc.
- The low atmospheric attenuation (10.6 μm) makes CO_2 laser suitable for open air communication.
- It is used in remote sensing.
- It is used in the treatment of liver and lung diseases.
- It is largely used in neurosurgery and general surgery.
- It is used to perform microsurgery and bloodless operations.