



# **18PYB101J    MODULE-5    LECTURE 8**

- **CO<sub>2</sub> Laser**



## CO<sub>2</sub> Laser

### Introduction

CO<sub>2</sub> lasers belong to the class of molecular gas lasers.

- In the case of atoms, electrons in molecules can be excited to higher energy levels, and the distribution of electrons in the levels define the **electronic state** of the molecule.

- Besides, these electronic levels, the molecules have other energy levels.



## Active medium

It consists of a mixture of  $\text{CO}_2$ ,  $\text{N}_2$  and helium or water vapour. The active centres are  $\text{CO}_2$  molecules lasing on the transition between the rotational levels of vibrational bands of the electronic ground state..

## Optical resonators

A pair of concave mirrors placed on either side of the discharge tube, one completely polished and the other partially polished.



## Pumping

- ✚ Population inversion is created by electric discharge of the mixture.
- ✚ When a discharge is passed in a tube containing  $\text{CO}_2$ , electron impacts excite the molecules to higher electronic and vibrational-rotational levels.
- ✚ This level is also populated by radiationless transition from upper excited levels.
- ✚ The resonant transfer of energy from other molecules, such as,  $\text{N}_2$ , added to the gas, increases the pumping efficiency.
- ✚ Nitrogen here plays the role that He plays in He-Ne laser.



A carbon dioxide ( $\text{CO}_2$ ) laser can produce a continuous laser beam with a power output of several kilowatts while, at the same time, can maintain high degree of **spectral purity** and **spatial coherence**.

In comparison with atoms and ions, the energy level structure of molecules is more complicated and originates from three sources: **electronic motions**, **vibrational motions** and **rotational motions**.



## Fundamental Modes of vibration of CO<sub>2</sub>

Three fundamental modes of vibration for CO<sub>2</sub>

- Symmetric stretching mode (frequency  $\nu_1$ )
- Symmetric bending mode ( $\nu_2$ ) and
- Asymmetric stretching mode ( $\nu_3$ ).

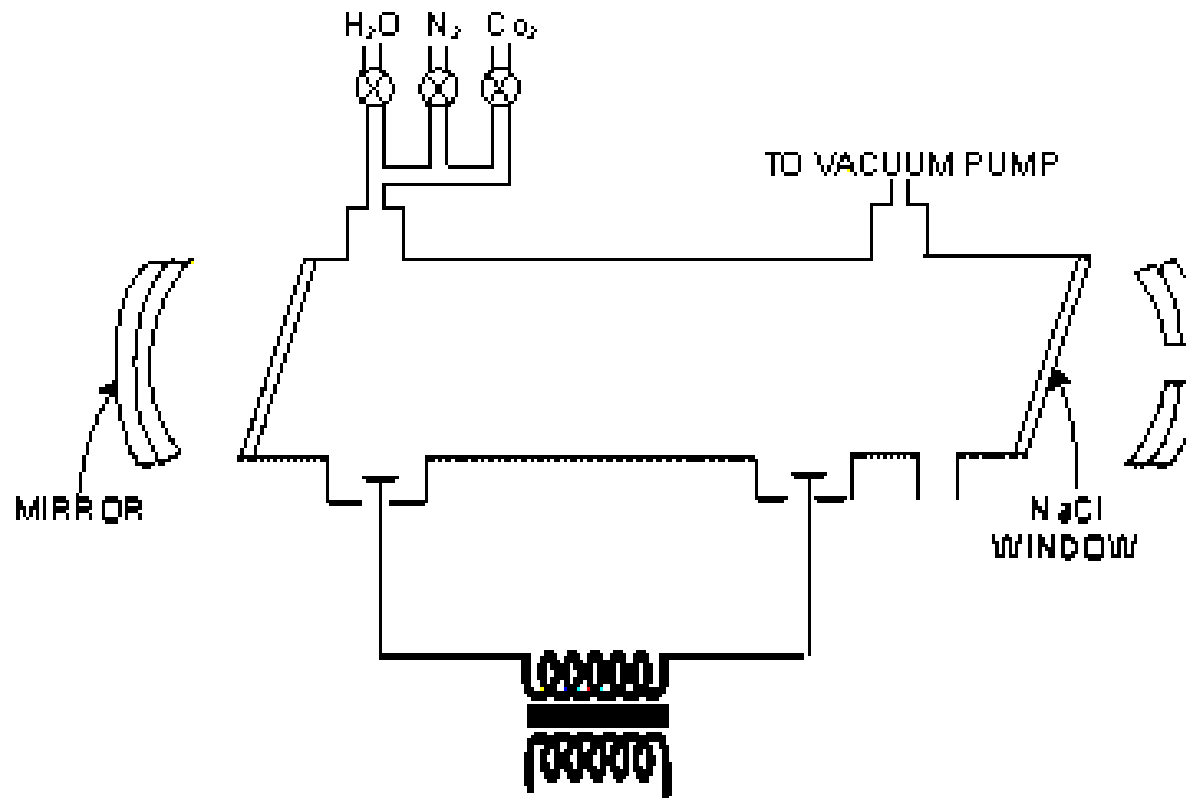
In the **symmetric stretching mode**, the oxygen atoms oscillate along the axis of the molecule simultaneously departing or approaching the carbon atom, which is stationary.



✚ In the **bending mode**, the molecule ceases to be exactly linear as the atoms move perpendicular to the molecular axis.

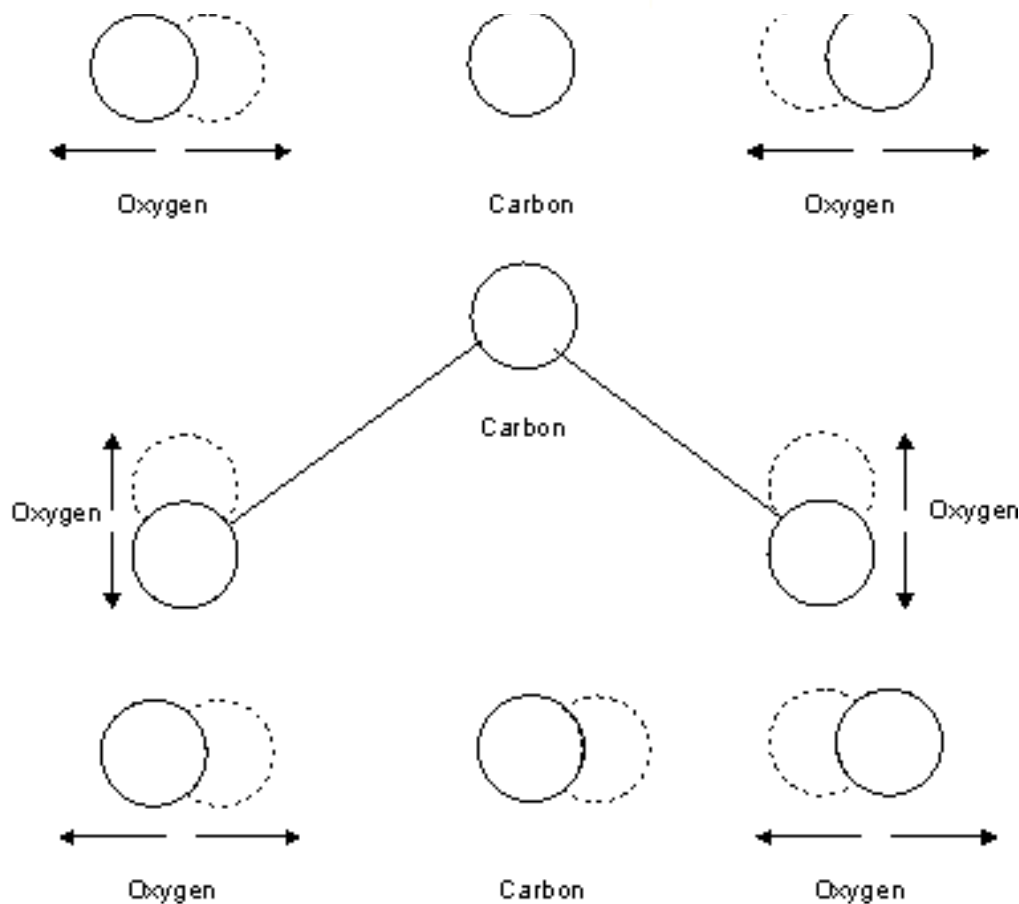
✚ In **asymmetric stretching**, all the three atoms oscillate: but while both oxygen atoms move in one direction, carbon atoms move in the opposite direction.

✚ The **internal vibrations** of carbon dioxide molecule can be represented approximately by linear combination of these three normal modes.



## CO<sub>2</sub> Laser





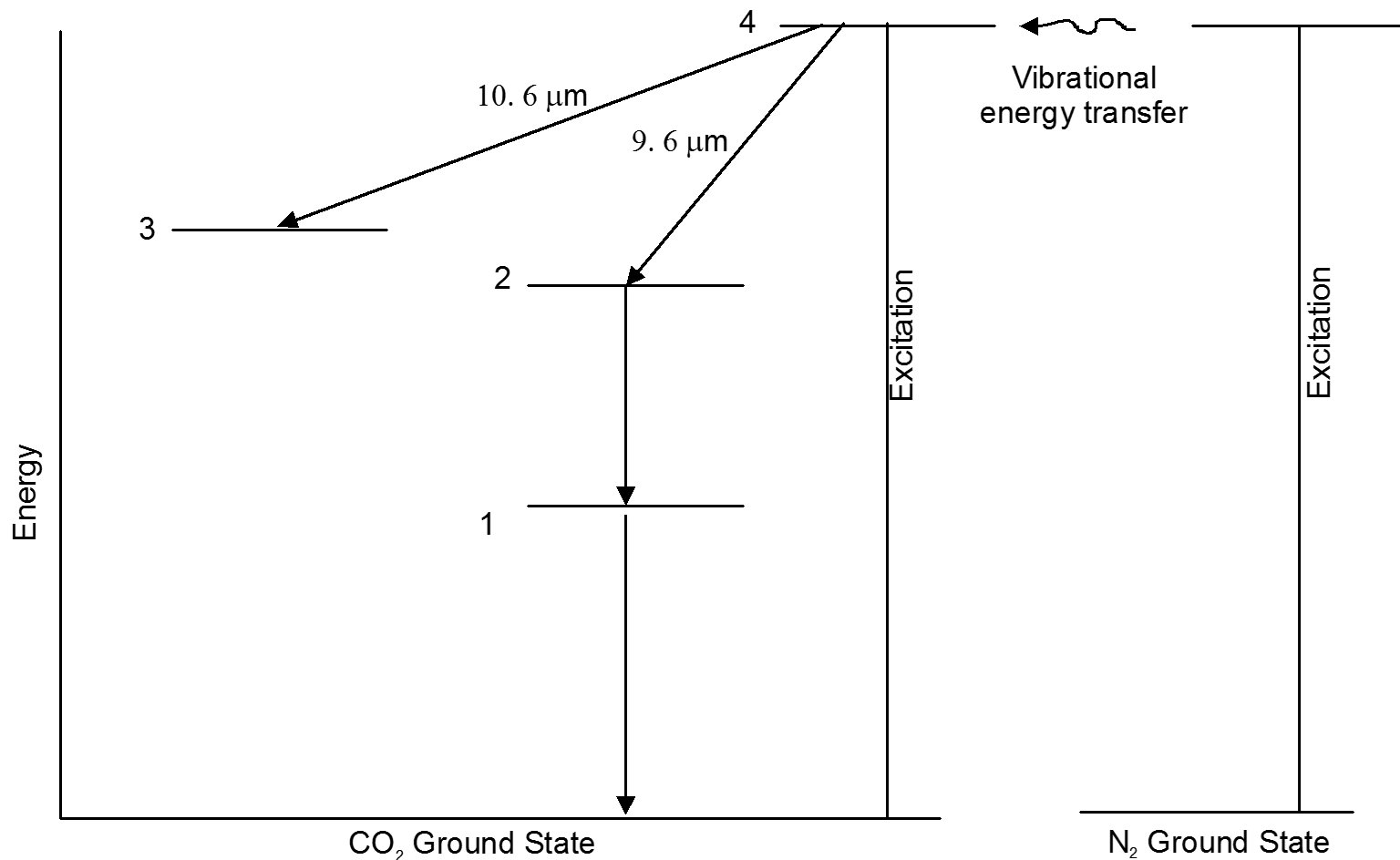
## Independent modes of vibration of $\text{CO}_2$ molecule



- ✚ The energy level diagram of **vibrational – rotational** energy levels with which the main physical processes taking place in this laser.
- ✚ As the electric discharge is passed through the tube, which contains a mixture of carbon dioxide, nitrogen and helium gases, the electrons striking nitrogen molecules impart sufficient energy to raise them to their first excited **vibrational-rotational** energy level.
- ✚ This energy level corresponds to one of the vibrational - rotational level of  $\text{CO}_2$  molecules, designated as level 4.



- + collision with  $\text{N}_2$  molecules, the  $\text{CO}_2$  molecules are raised to level 4.
- + The lifetime of  $\text{CO}_2$  molecules in level 4 is quite significant to serve practically as a metastable state.
- + Hence, population inversion of  $\text{CO}_2$  molecules is established between levels 4 and 3, and between levels 4 and 2.
- + The transition of  $\text{CO}_2$  molecules between levels 4 and 3 produce lasers of wavelength 10.6 microns and that between levels 4 and 2 produce lasers of wavelength 9.6 microns.



## Energy level diagram



- ✚ The **He molecules** increase the population of level 4, and also help in emptying the lower laser levels.
- ✚ The molecules that arrive at the levels 3 and 2 decay to the ground state through radiative and collision induced transitions to the lower level 1, which in turn **decays to** the ground state.
- ✚ The power output of a  $\text{CO}_2$  laser increases linearly with length. Low power (upto 50W) continuous wave  **$\text{CO}_2$  lasers** are available in sealed tube configurations.



- Some are available in sizes like torches for medical use, with 10-30 W power.
- All high power systems use fast gas-flow designs.
- Typical power per unit length is 200-600 W/m.
- Some of these lasers are large room sized metal working lasers with output power 10-20 kW.
- Recently CO<sub>2</sub> lasers with continuous wave power output exceeding 100 kW.
- The wavelength of radiation from these lasers is 10.6μm.