18PYB101J MODULE-5 LECTURE 8

- CO_2 Laser

CO_2 Laser

Introduction

CO_2 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 CO_2, N_2 and helium or water vapour. The active centres are 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 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, 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 (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.

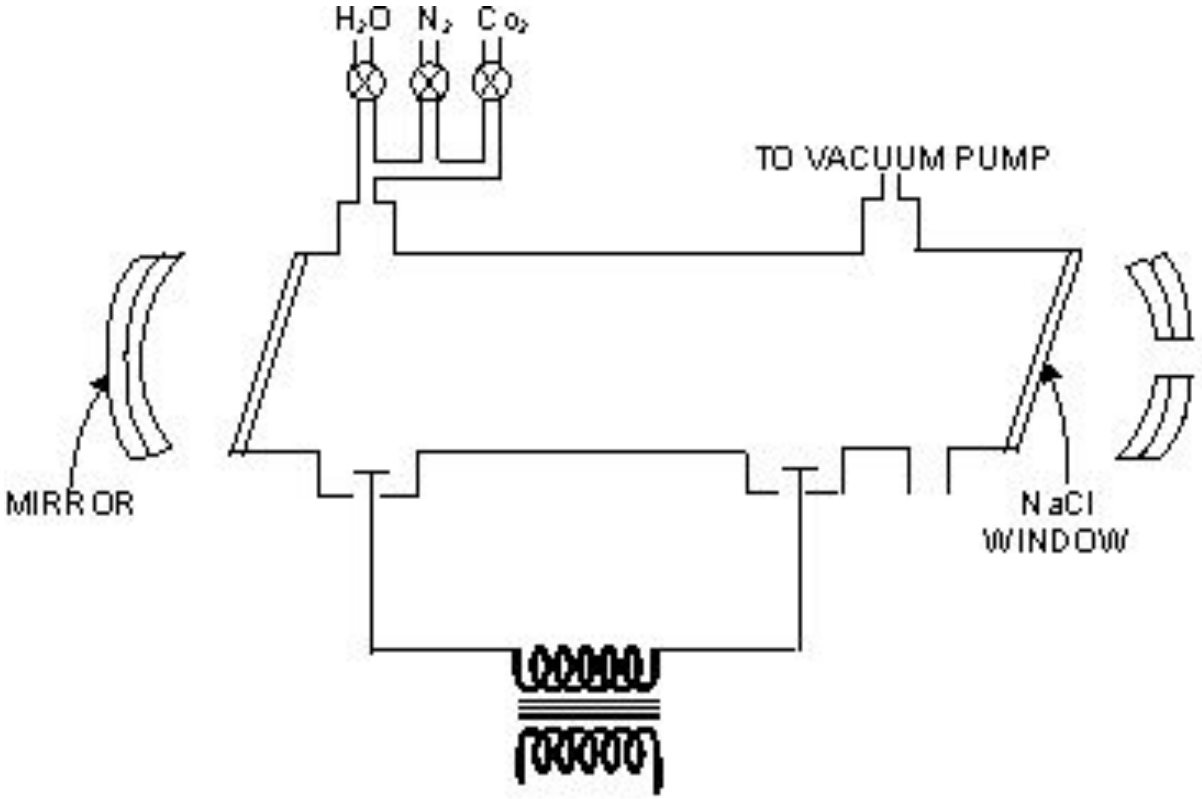
Fundamental Modes of vibration of CO_2

Three fundamental modes of vibration for CO_2

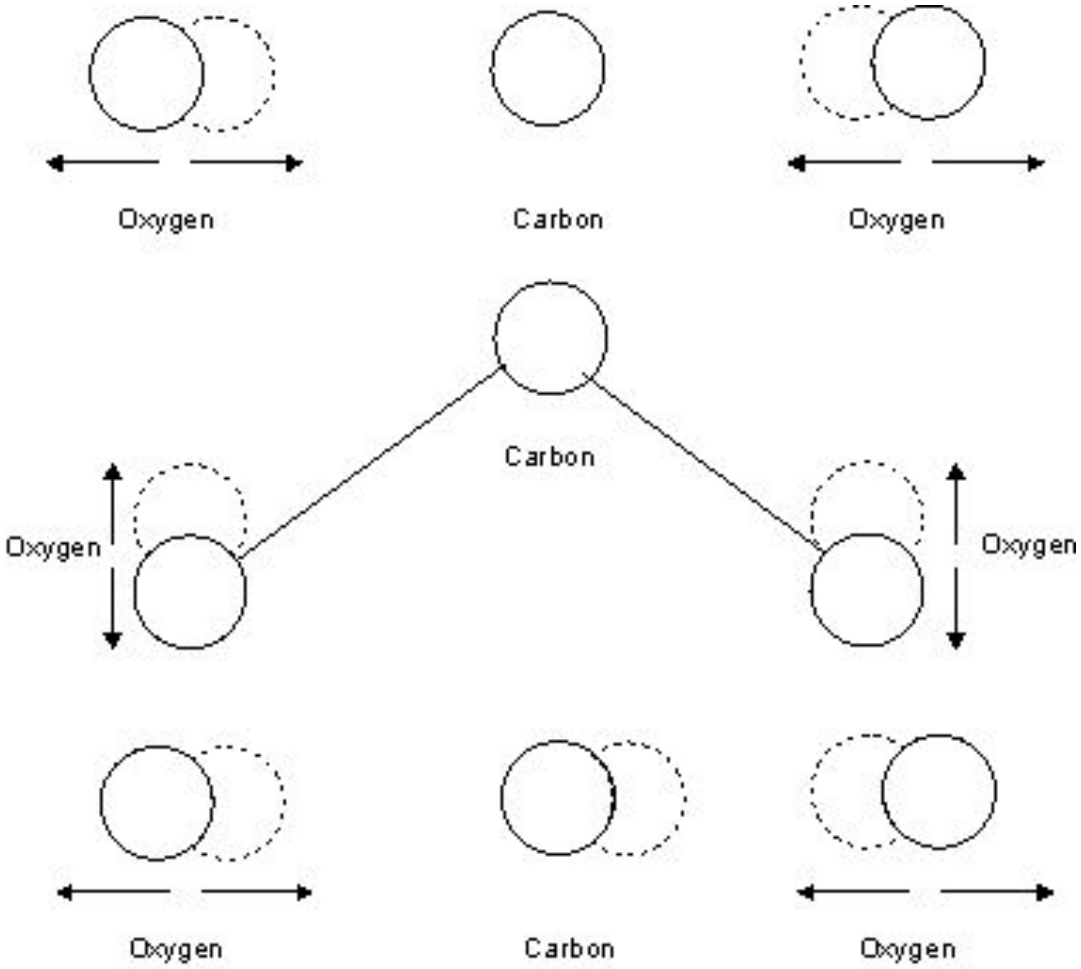
- Symmetric stretching mode (frequency ν_1)
- Symmetric bending mode (ν_2) and
- Asymmetric stretching mode (ν_3).

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.



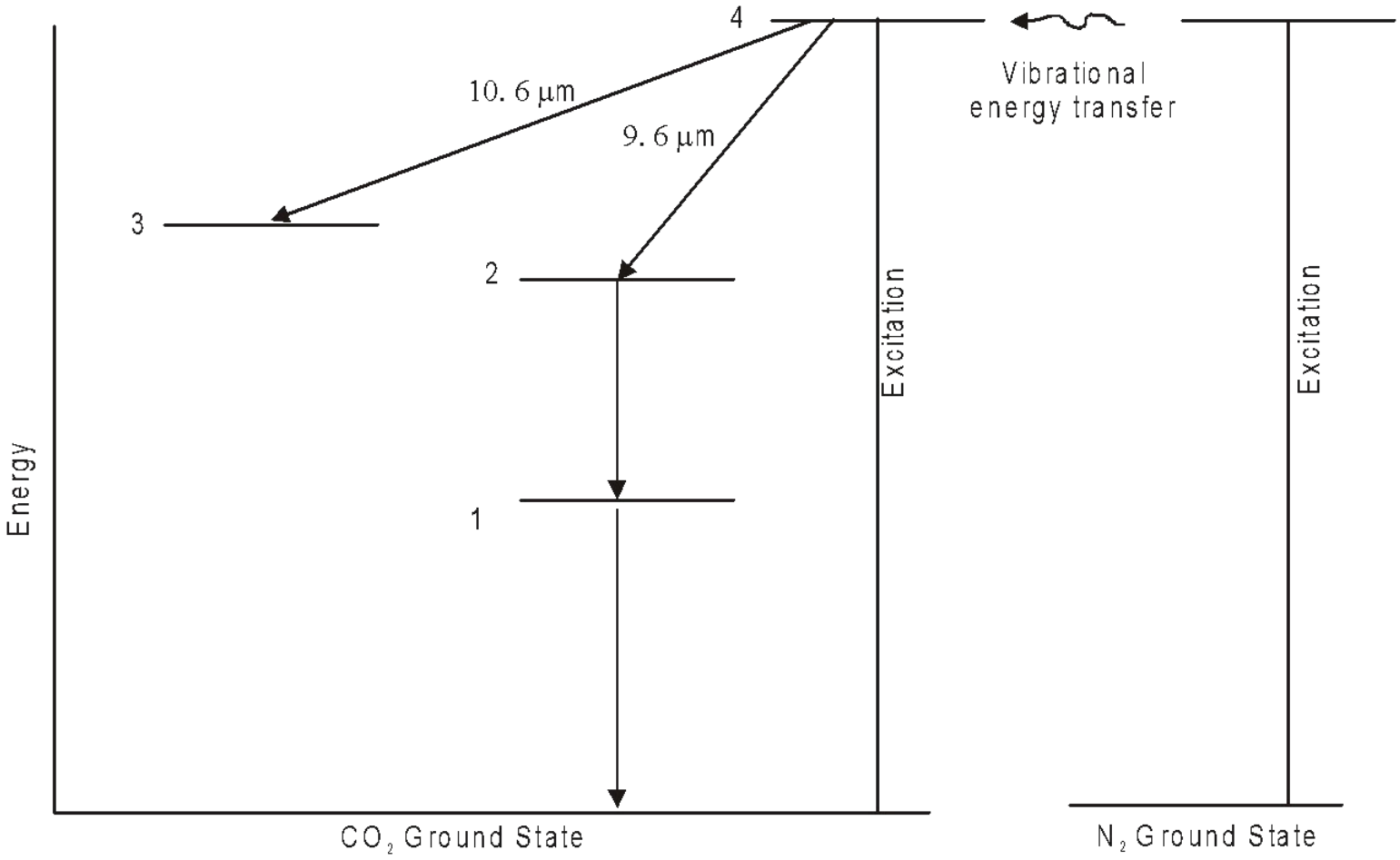
CO_2 Laser



Independent modes of vibration of 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 CO_2 molecules, designated as level 4.

- collision with N_2 molecules, the CO_2 molecules are raised to level 4.
- The lifetime of CO_2 molecules in level 4 is quiet significant to serve practically as a metastable state.
- Hence, population inversion of CO_2 molecules is established between levels 4 and 3, and between levels 4 and 2.
- The transition of 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 CO_2 laser increases linearly with length. Low power (upto 50W) continuous wave 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-floe 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_2 lasers with continuous wave power output exceeding 100 kW.
- The wavelength of radiation from these lasers is 10.6 μm.