

### 1.1.7 Carbon-Dioxide (CO<sub>2</sub>) Laser

Lasing action in a CO<sub>2</sub> molecule was first demonstrated by C. Patel in 1964. He transmitted an electric discharge pulse through pure CO<sub>2</sub> gas in a laser tube, and got a small laser output. CO<sub>2</sub> is the gas in which the lasing process occurs, but other gas additives to the laser tube improve the total efficiency of the laser. The standard CO<sub>2</sub> laser includes in the active medium a mixture of CO<sub>2</sub> with N<sub>2</sub> and He. The optimal proportion of these 3 gases in the mixture depends on the laser system and the excitation mechanism. In general, for a continuous wave laser the proportions are: CO<sub>2</sub>:N<sub>2</sub>:He - 1:1:8

CO<sub>2</sub> is a linear molecule, and the three atoms are situated on a straight line with the Carbon atom in the middle. In figure 1.6 the three vibrational modes of CO<sub>2</sub> molecule are illustrated:

1. Symmetric stretch mode ( $\nu_1$ ).
2. Bending mode ( $\nu_2$ ).
3. Asymmetric stretch mode ( $\nu_3$ ).

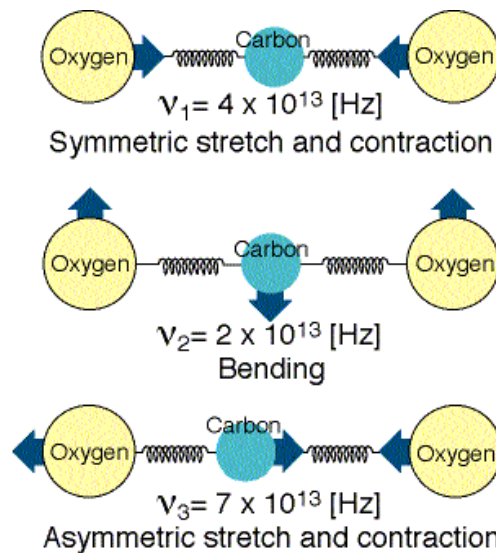


Figure 1.6: Oscillation Modes of CO<sub>2</sub> Molecule

### Lasing transitions in CO<sub>2</sub> laser

Lasing transitions in CO<sub>2</sub> laser occur when the molecule is going from higher energy level of the asymmetric mode into one of the other two, as can be seen in figure 1.7.

1. The transition to the symmetric stretching mode corresponds to the wavelength  $10.6 \mu\text{m}$ .
2. The transition to the bending mode corresponds to the wavelength  $9.6 \mu\text{m}$ .

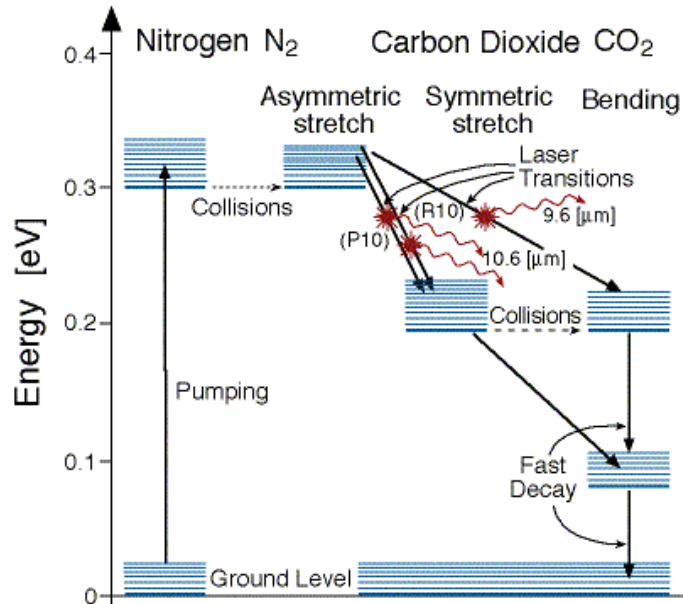


Figure 1.7: Energy Level Diagram of CO<sub>2</sub> Laser

Each of the vibrational energy level is subdivided into many rotational levels. Transitions can occur between vibrational energy levels with different rotational levels, so there are many lasing lines around the main vibrational transitions.

### CO<sub>2</sub> laser operation

Electrical discharge is created in the laser tube. The energy of the accelerated electrons is transferred by collisions to the Nitrogen molecules and to the CO<sub>2</sub> molecules. Nitrogen molecules help in the process of the excitation of the CO<sub>2</sub> molecules.

The first vibrational energy level of the Nitrogen molecule is very similar to the asymmetric stretching mode of the CO<sub>2</sub> molecule, so energy can be easily transferred from the excited Nitrogen molecules to the CO<sub>2</sub> molecules. Helium molecules are added to the gas mixture in order to:

1. Empty the lower laser energy level so that population inversion is maintained.
2. Stabilize the electrical discharge by taking heat away from the lasing area.

## Types of CO<sub>2</sub> Lasers:

There are many types of CO<sub>2</sub> lasers, all based on the same physical principles. The differences between them are in their structure, excitation mechanism, and the output radiation. A few CO<sub>2</sub> lasers are described below.

### a. Flowing CO<sub>2</sub> gas lasers

In these lasers a fresh gas mixture is flowing continuously through the laser tube while lasing lasts. Flowing gas is used when the maximum power is needed out of the CO<sub>2</sub> laser. The gas flows along the tube and is released out into the atmosphere (since it is non poisonous). These lasers are very simple, and the requirements from the gas purity are small. Hundreds of Watts can be achieved at the output of these lasers.

### b. Sealed off CO<sub>2</sub> laser

The gas laser is filled with the appropriate mixture of gasses and sealed (as we saw in He-Ne laser). High electric voltage is applied to electrodes at both ends of the gas tube. The accelerated electrons excite the gas molecules.

The problem with sealed off lasers is the dissociation of the CO<sub>2</sub> molecules into CO and Oxygen with time. To reduce this effect, a catalyzing agent is added to the gas mixture. This catalyzing agent reverses the dissociation reaction and restores the CO<sub>2</sub> molecule which is required for lasing. Sealed off CO<sub>2</sub> lasers are usually limited to output power of less than 200 watts. For higher output power it is necessary to take away the heat generated inside the laser, and a flowing gas is needed.

Sometimes a gas reservoir is added to the sealed off tube to allow some refreshment of the lasing gasses from the reservoir to the tube. The new class of sealed CO<sub>2</sub> lasers is made from metal with no glass tube.

### c. CO<sub>2</sub> Laser inside a waveguide

When the laser tube diameter is reduced to a size of about 1 millimeter, a waveguide is made. The radiation inside the small diameter tube is confined to move along the tube, with low loss. Using ceramic tubes, very small CO<sub>2</sub> lasers can be made. These small CO<sub>2</sub> lasers can produce up to 50 Watts of continuous wave radiation.

### Transverse Flow CO<sub>2</sub> gas lasers

When the gas flow inside the laser is perpendicular to the laser axis, it is possible to have a much larger flow since the distance is very short. Since cooling by gas flow is very efficient, it is possible to get very high power output out of these lasers.

Both the gas flow and the electric discharge in these lasers are along the width of the laser. Thus, the distance between the electrodes is short, so electric discharge can be achieved even for gas at very high pressure (up to a few atmospheres). Transverse flow is used for very high power CO<sub>2</sub> lasers.

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

- High output power. Commercial CO<sub>2</sub> Lasers produce more than 10000 Watts continuously.
- Output spectrum is in the Infra-Red (IR) spectrum: 9.6 μm , 10.6μm
- Very high efficiency (up to 35%).
- Can operate both continuously or pulsed.
- Average output power is 75 W/m for slow flow of gas, and up to few hundreds W/m for fast gas flow.
- Very simple to operate, and the gasses are non-toxic.

### CO Laser

This laser is very similar to the CO<sub>2</sub> laser, except for the active gas - CO. The spectrum output of these lasers is: 5-6 μm. One of the problems with this laser is the gas CO which is poisonous.