CO_2 Lasers

The first CO_2 laser operated at the wavelength of 10.6μm in 1964. Because it is one of the most efficient lasers, with 10% conversion efficiency for commercial models, it is widely used in laser cutting, welding, drilling, and surface treatment. It is currently the most powerful material processing laser with commercial laser being offered up to 45 kW.

1. Principle of Operation

CO_2 laser is a molecular laser. The key lasing material is carbon dioxide molecule. It can take on various energy states depending on the form of vibration or rotation. The basic energy network possible with carbon dioxide is shown in Figure 7. The gas mixture in a carbon dioxide laser is subject to an electric discharge causing the low pressure gas (usually around 30-50 torr) to form a plasma. In the plasma, the molecules take up various excited states as expected from the Boltzmann distribution. Some will be in the upper state (00^o1) which represents an asymmetric oscillation mode. By chance this molecule may lose its energy by collision with the walls of the cavity or by spontaneous emission. Through spontaneous emission the state falls to the symmetric oscillation mode (10^o0) and a photon of light of wavelength 10.6 μm is emitted travelling in any direction by chance. One of these photons, again by chance, will be travelling down the optics axis of the cavity and will start oscillating between the resonator mirrors.

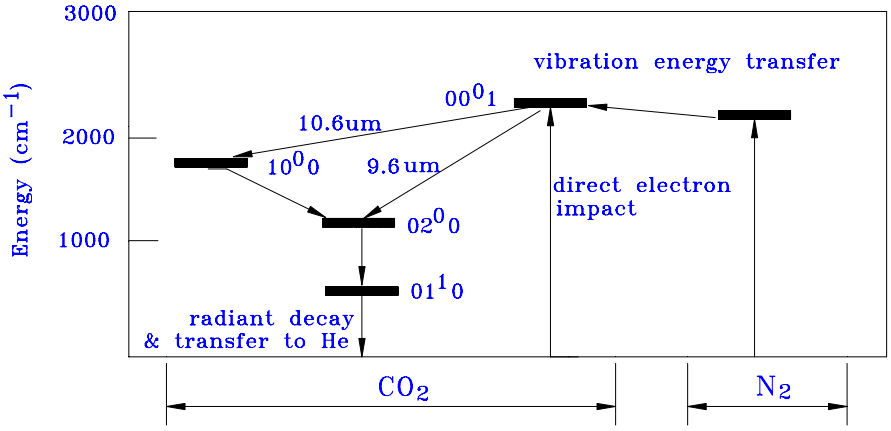

Fig. 1 Simplified energy-level diagram of the CO_2 molecule

In general, the working material in a CO_2 laser is a mixture of CO_2, He, and N_2. N_2 plays the role as a buffer gas, and its molecules resonantly transfer the excitation energy to CO_2 molecules. Because the relaxation of the level (01^10) is the bottleneck, He plays the role as a heat sink to transfer the energy of the level (01^10) to He atoms.

2. Types of CO_2 lasers

The way the waste heat is rejected (or gas cooling method) has a large influence on the laser system design. In principle, it can be performed by two possible methods. The first method is based on the automatic process of natural diffusion of the heated gas to the tube wall, which is the operating principle of the sealed, and slow axial flow lasers. The second method is based on the gas forced convection, which is the operating principle of the fast flow lasers.

In general, there are 5 major types of CO_2 lasers:

- sealed or no-flow

- slow axial flow
- fast axial flow
- fast transverse flow
- transverse excited atmosphere (TEA)

The sealed or no flow CO_2 laser is often used in beam deflected laser marking. Its discharge tube is completely sealed-off. The laser beam quality is excellent. It is very easy to maintain as in most cases the whole discharge tube is replaced with a new one and the used one is sent back for gas-refill. There is no need for a separate gas supply system. Only a fewer connections to the laser head are needed. It is therefore compact and light. However, its output power is low (generally less that 200 W).

The TEA CO_2 laser is often used in mask marking. It operates in pulsed mode only. The gas flow is low and the gas pressure is high. The excitation voltage is around tens thousand volts. The laser beam energy distribution is uniform over a relatively large area. Its peak power is very high up to 10^{12} W as its pulse duration is very small. However it is very difficult to focus its laser beam to a small spot due to multimode operation.

3. Pumping power supply

In general, there are three key types of pumping power supplies for CW CO_2 lasers, i.e. DC, HF and RF. The DC power supply is simple in design. The current in HF power supplies alternate at a frequency between 20 to 50 kHz. HF power supplies are compact in size and efficiency is higher compared to DC power supplies. The current in RF power supplies alternates at a frequency between 2 to 100 MHz. The voltage and the efficiency are lower compared to DC power supplies.