Perfect Laser Technologies

TECHNICAL BULLETIN # 13

Gases Galore (or how do CO^2 lasers work?)

Your LASER (Light Amplification by Stimulated Emission of Radiation) produces a narrow, powerful beam of light at a single specific wavelength. Lasers transform one form of energy (electricity, photons, radiation) into another, i.e. laser light. This produces a laser beam capable of travelling over large distances. Focusing it onto a small spot creates very high temperatures.

Typically, there are two types of laser used for materials processing – gas lasers and solid-state lasers. The CO^2 laser is most frequently used for laser cutting, although more powerful fiber lasers are now being used to cut steel. The laser medium is a gas or, more accurately, a mixture of gases with CO^2 as the active ingredient.

The group of solid-state lasers covers a number of systems such as Nd:YAG or Yt:YAG, diode lasers and other fiber lasers, where the laser medium is a solid. Consequently, these lasers do not require gases to generate the laser beam.

As their name implies, gas lasers rely on gases to generate the laser beam. The most popular is the CO^2 laser where CO^2 is the active laser medium. The laser gas mixture contains Carbon Dioxide (CO^2) but also other components such as Helium (He) and Nitrogen (N). Depending on the type of laser, small amounts of other gases such as Oxygen (O), Carbon Monoxide (CO), Hydrogen (H) or Xenon (Xe) may be required in the mix.

CO^2 is the gas that is active in generating the laser light, i.e. infrared radiation with a wavelength of 10.6µm (10600nm). The radiation is created by transitions between different vibrational energy levels in the Carbon Dioxide molecule.

Laser radiation is created when:

1. CO^2 molecules are excited to an upper laser level by collision with electrons in the electric discharge.
2. 10.6µm laser radiation is created by transitions from the upper level to a lower laser level.
3. After reaching the lower laser level, the CO^2 molecules are transferred to the lowest energy level by collisions with other gas molecules. This is called “relaxation”.

It is possible to run a CO^2 laser using only CO^2 as the constituent laser gas, but in order to create the power required for laser cutting and engraving, it is necessary to add at least Nitrogen and Helium.

It is relatively easy to excite a Nitrogen (N) molecule to its first vibrational energy level via an electric field or discharge. This first energy level of Nitrogen has almost the same energy content as the upper level of CO^2. Transfer of vibrational energy from N to CO^2 is achieved through collision between the two molecules. Thus it is easier to excite the upper laser level of CO^2 by introducing Nitrogen. This results in higher laser power.

Helium is to help CO^2 to “relax” (to move from the lower to the lowest energy level and re-enter the excitation process). Helium atoms collide with CO^2 molecules and vibrational energy is transferred from the CO^2 to the He. As a result, higher laser power can be obtained. Helium also helps to conduct heat away from the electric field or the electric discharge (it has the highest heat-conduction coefficient of all gases). This is essential for CO^2 lasers, where excess heat must be conducted to the walls of the discharge tube.

Some lasers may also require small additions of CO, O, H and/or Xe, which trigger the chemical process in the resonator. CO and O counteract the decomposition (dissociation) of CO^2. Hydrogen has a similar effect and can contribute to a more uniform electric discharge in the resonator. Output power and efficiency can also be improved by the addition of Xe. This has the lowest ionisation potential and largest ionisation cross-section, thus becoming the primary source of ions in the discharge.

Oxygen

Symbol: O
Electron configuration: [He] 2s22p4
Atomic mass: 15.999 u
Atomic number: 8
Electrons per shell: 2,6
Discoverers: Joseph Priestley, Carl Wilhelm Scheele

Carbon

Symbol: C
Atomic mass: 12.0107 u ± 0.0008 u
Atomic number: 6
Electron configuration: [He] 2s22p2
Electrons per shell: 2, 4
Electronegativity: 2.55

Helium

Symbol: He
Atomic number: 2
Atomic mass: 4.002602 u ± 0.000002 u
Boiling point: -268.9 °C
Electron configuration: 1s2
Discoverers: Pierre Janssen, Norman Lockyer

Nitrogen

Symbol: N
Atomic mass: 14.0067 u ± 0.0001 u
Electron configuration: [He] 2s22p3
Atomic number: 7
Boiling point: -195.8 °C
Discoverer: Daniel Rutherford

Hydrogen

Symbol: H
Atomic mass: 1.00794 u ± 0.00001 u
Atomic number: 1
Boiling point: -252.9 °C
Electronegativity: 2.2
Discoverer: Henry Cavendish

Xenon

Symbol: Xe
Electron configuration: [Kr] 4d105s25p6
Atomic number: 54
Atomic mass: 131.293 u ± 0.006 u
Boiling point: -108.1 °C
Discovered: 1898

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January 2018