CO_2 as a laser gas

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Carbon dioxide (CO_2) lasers were one of the earliest gas lasers to be developed in 1964 by Bell Labs, and some claim them to be one of the most powerful continuous lasers available today.

The active laser medium is a gas discharge, which is either air or water cooled, in part dependent upon the power being applied. Applications are diverse in medicine and dentistry; in the industrial sector, they range from laser marking of various materials, to processing of glass, ceramics, plastics, and wood. In the metallurgical sector, uses include cutting and marking metals from copper to stainless, to aluminum. They are also used in the defense industry, for anti-missile weapons.

In the medical field, applications for CO_2 lasers include dermatology, plastic surgery, ophthalmology, neurological surgery, and more. CO_2 resurfacing of skin can precisely remove thin layers of skin with minimal heat damage to the surrounding structures. The field of CO_2 laser resurfacing is rapidly changing and improving. For laser resurfacing applications, a new generation of CO_2 lasers uses very short pulsed light energy (ultra-pulsed) or continuous light beams, which are delivered in a scanning pattern. There is also a trend to remove wrinkled skin successfully via CO_2 lasers. As to the role in dermatology, this laser has long been used to remove scars, warts, birthmarks, enlarged oil glands on the nose, and other skin conditions.

CO_2 lasers' use in medicine dates back to about 1984. Over time, there have been improvements in performance, size reduction, operating cost reductions, and reliability for industrial lasers. Such improvements have been with radio frequency (RF) and pulsed DC excitation, new sealed plasma tubes, and improvements in pumping flowing gas lasers, with highly durable all-metal construction.

The CO_2 laser consists of a gas mixture that includes nitrogen, helium, CO_2, xenon or water vapor, and sometimes hydrogen. The gas mixture acts as a gain medium, and the laser is pumped through an electrical discharge. During electrical discharge, the nitrogen molecules are excited to their metastable vibrational state, and they collide with the CO_2 molecules to transfer their energy. The CO_2 laser can be operated in radio frequency range, using AC or DC current.

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It emits an infrared light at standard wavelengths of 9.6 and 10.6 micrometers.

The goal to shrink laser footprints has been a major consideration. The two principal components in a CO_2 laser are the laser head, or resonator, and the power supply.

As to metal cutting applications for CO_2 lasers, pulsing the output beam allows to work with thicker and tougher materials. The laser power must reach a critical level for processing of thicker and tougher cutting and engraving to occur; below this level, the beam merely heats or melts the material to be treated, thus wasting valuable laser power and increasing the size of the heat-affected zone.

State-of-the-art, completely-sealed lasers have sealed optics and metal construction. The lifetime for such lasers is more than 20,000 hours of service. There are laser robots which are specially optimized for 3D cutting and perforation with CO_2, as well.

Some of the limitations in industrial welding and processing include the limits associated with laser light cables. Also, there are restrictions imposed by the wavelength, with respect to absorption and maximum resolution in micro processing. However, the CO_2 laser is a very important laser type for industrial processing since they can reach unrivaled power levels, and have a relatively low cost. Due to their high powers and high drive voltages, CO_2 lasers can raise serious issues of laser safety. On the other hand, their long operation wavelength makes them relatively eye-safe at low intensities.

Typical industrial applications

Laser cutting of metals with flatbed or 3D cutting systems is the most frequent applications for CO_2 lasers. State-of-the-art processing with standard machines features quality cuts of 25 millimeter stainless steel.

In terms of high power and precision, low investment costs, there is currently no alternative to CO_2 lasers. For laser welding, the beam source selection depends on specific factors. The material thickness and welding speed are the most prominent factors influencing the laser the laser power and property requirements.

Due to the thickness of the materials,

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in ship building and heavy machinery construction, CO_2 lasers are almost exclusively used. Stainless steel welding, and transmission component welding are typical examples of CO_2 laser welding jobs. Both are high production applications, with low costs when CO_2 laser welding is employed.

Furthermore, the CO_2 laser wavelength of 10.6 micrometers is advantageous in the processing of glass, ceramics, and plastics.

CO_2 lasers demonstrate their full capacity in stationary scanner welding. The beam quality of 6 kw lasers enables welding with a focal length of about 1,500 millimeters. Together with the scanner technology, this can cover a working range with a 1,500 millimeter diameter and positioning speeds of 1,000 meters per minute.

Due to their higher power levels, CO_2 lasers are commonly used in further applications, including cutting die board, wood, and in plastics.

This group of CO_2 laser applications would exhibit high absorption at 10.6 micrometers, and requiring moderate power levels of 120-200 watts. When thinking of welding with CO_2 lasers, the metals can be diverse, including copper, aluminum, and stainless steel, where multi-kilowatt powers would be required.

Laser construction and types

Because CO_2 lasers operate in the infrared, special materials are necessary for their construction. There are diverse types of CO_2 lasers on the market today. These include the following:

- For laser powers between a few watts and several hundred watts, it is common to use sealed-tube or no-flow lasers.
- High powered diffusion-cooled slab lasers. Several kilowatts of output are possible.
- Fast axial flow lasers and fast transverse flow lasers are also suitable for multi-kilowatt continuous wave output powers. An external cooler is used with these types of laser.
- Transverse excited atmosphere (TEA) lasers use a high gas pressure. These often produce average output powers below 100 watts, but can be made for powers of tens of kilowatts.
- Gas dynamic CO_2 lasers for multi-megawatt powers, such as for anti-missile weapons, where the energy is not produced by a gas discharge, but by a chemical reaction in a rocket engine.

The concepts differ primarily in the technique of heat extraction, and in the gas pressure and electrode geometry used. In low-power, sealed-tube lasers, such as for laser markings, waste heat is transported to the tube walls by diffusion or a slow gas flow. High power CO_2 lasers utilize a fast forced gas convection, which may be along the beam direction, or in the transverse direction for the highest powers.

For the gas companies, they should explore all applications surrounding CO_2 laser usage, and work to expand the market, where uses do not currently exist for their customers, or where other types of lasers are used in industry. All of the tonnage sold for such applications is critically important as a growth engine in the CO_2 industry, and is important to developing a well-rounded CO_2 market for the product. There are significant and complex details, specifications, and technologies involved in such devices, and this is likely to grow over time. gw

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