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CO2 as a Laser Gas

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Special to The Digest

CO2 lasers were one of the earliest gas lasers to be developed. The development occurred in 1964 by Bell Labs, and remains one of today's most useful lasers; which some claim to be one of the most powerful continuous lasers available as of late. The active laser medium is a gas discharge, which is either air or water cooled, in part dependent upon the power being applied. Applications range from a diverse number of uses in medicine and dentistry. Then in the industrial sector, from laser marking of various materials, to processing of glass, ceramics, plastics, and wood. Then, the metallurgical sector, cutting and marking metals from copper to stainless, to aluminum. In the defense industry, for anti-missile weapons. There is a wide range of laser types, and modes of operation. This industry is both highly diverse and very interesting.

I have written about the application of CO2 lasers in medicine, which can also be found in dentistry. As to the medical field, the applications are diverse. These applications for CO2 lasers include dermatology, plastic surgery, ophthalmology, neurological surgery, and more. CO2 resurfacing of skin can precisely remove thin layers of skin with minimal heat damage to the surrounding structures. The field of CO2 laser resurfacing is rapidly changing and improving. For laser resurfacing applications, a new generation of CO2 lasers uses very short pulsed light energy (ultra-pulsed) or continuous light beams, which are delivered in a scanning pattern. As to the baby boomers, an appeal today is to remove wrinkled skin successfully via CO2 lasers. Therefore, sun damaged and wrinkled skin are a strong market for those who wish to maintain their beauty. 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. The use in medicine dates back about 45 years, to about 1984.

During 1984, CO_2 lasers were approved by the FDA (the food and drug administration) – where the device was considered to have a high level of reliability and precision. The discussion ahead is largely geared toward industrial applications, and the laser itself. Over time, improvements have occurred in the performance, size reduction, operating cost reductions, and improved 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. 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. Further, power supplies have become smaller. 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 would be 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 – where 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

Beyond medical applications, which have been reviewed in the past, would be the industrial devices. 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. The typical cutting machine uses a machine – mounted laser for flexibility of use and maximum machine utilization. In terms of high power and precision, low investment costs, there is currently no alternative to CO2 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, in ship building and heavy machinery construction, CO2 lasers are almost exclusively used. Stainless steel welding, and transmission component welding are typical examples of CO2 laser welding jobs. Both are high production applications, with low costs when CO2 laser welding is employed. Furthermore, the CO2 laser wavelength of 10.6 micrometers is advantageous in the processing of glass, ceramics, and plastics with CO2 lasers.

CO2 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, CO2 lasers are commonly used in further applications, including cutting die board, wood; and as mentioned before in plastics. This group of CO2 laser applications would exhibit high absorption at 10.6 micrometers, and requiring moderate power levels of 120-200 Watts. When thinking of welding with CO2 lasers, the metals can be diverse, including copper, aluminum, and stainless steel; where multi – kilowatt powers would be required.

Laser construction and types

Because CO2 lasers operate in the infrared, special materials are necessary for their construction. There are diverse types of CO2 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 CO2 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 of sorts.

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. The beam quality can be very high. High power CO2 lasers utilize a fast forced gas convection, which may be along the beam direction, or in the transverse direction – for the highest powers.

About the author

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