CO LASERS ENABLE UNIQUE PROCESSES

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While carbon monoxide (CO) lasers were first built over 50 years ago, they have not been used in industry due to lifetime and reliability limitations. This situation has now changed dramatically with the development of new CO laser technology from Coherent. This has enabled the production of sealed CO lasers which operate at very high output powers, with excellent efficiency at room temperature, and which demonstrate lifetimes in the thousands of hours range. Here we review how the unique output characteristics of CO lasers lead to significant benefits in some important commercial applications.

Mid-IR wavelength advantages

CO lasers output in the 5 µm spectral range which offers two important advantages for some applications compared with the long-wave infrared (10.6 µm) output of the widely used CO_2 laser. Firstly, many metals, films, polymers, PCB dielectrics, ceramics and composites exhibit significantly different absorption at the shorter wavelength. When the absorption is higher at the shorter wavelength, material can be processed more efficiently using lower laser power, and with a smaller heat affected zone (HAZ). On the other hand, when the transmission is higher at the shorter wavelength, the light penetrates further into the material, which can also be advantageous.

The second advantage of shorter wavelengths is that they can be focused to smaller spot sizes due to diffraction, which scales linearly with wavelength. For example, the minimum spot size achieved in practice in industrial applications for CO_2 lasers is 70-80 µm, whereas the CO laser can achieve practical spot sizes in the 30-40 µm range. This means that at a given power, the CO laser spot can have a power density (fluence) that is four times higher as compared to the CO_2 laser. When combined with stronger absorption in some materials at 5 µm, this enables these materials to be processed with a CO laser at significantly lower powers.

Glass cutting

CO_2 lasers are already employed in cutting the thin (< 1 mm thick) glass sheets used in many smart phone and tablet displays. However, the 10.6 µm output of the CO_2 laser is much more strongly absorbed by glass than the 5 µm CO laser output. This lower absorption allows the light to penetrate deeper into the glass. Therefore, heat is introduced to the glass internally and does not rely solely on diffusion from the surface. This eliminates surface melting, avoids the creation of cracks, and significantly reduces residual stress in the glass. The result is a better quality scribe yielding a stronger cut piece with higher bend strength, plus a wider process window for the manufacturer.

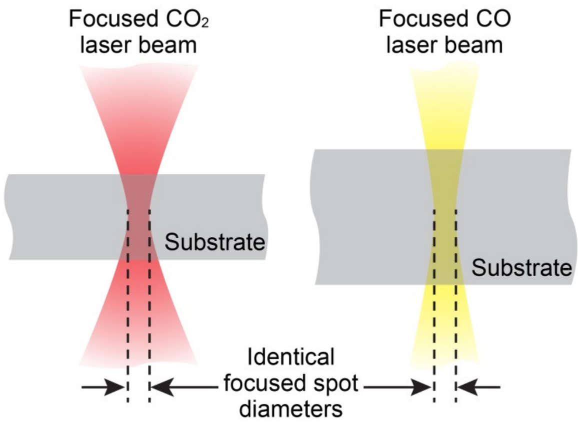

Figure 1: When focused to a given spot size, the shorter wavelength CO laser beam has a larger depth of focus than the CO2 laser. This yields higher fluence over a longer distance along the optical axis, which increases the thickness of the substrate that the laser can scribe.

The other advantage of CO lasers in glass cutting is their ability to support the cutting of curves. This benefits smartphone display applications because curved or shaped corners are often required to accommodate buttons, controls, LEDs and camera lenses.

CO laser glass cutting has proven most effective with substrates in the 50 µm to 700 µm range. Specifically, in this technique, a defect is first created by a mechanical or laser process and then propagated by moving the CO laser beam in the desired shape. This creates a through cut in the glass. Free-form shapes can be cut in glass thicknesses of up to 300 µm, and straight line cuts can be made in up to 700 µm thick substrates. There is no need for cooling air or water with this CO laser process.

For thicker glass (>700 µm depending on the glass), scribing can be performed with a CO laser, accompanied with cooling, followed by mechanical separation. This method works well for non-strengthened glass, and particularly for soda lime and borosilicate glass. The latter material is particularly problematic for CO_2 lasers.

For thicker soda lime and borosilicate glasses (>1 mm), work at the Laser Zentrum Hannover has also shown that the CO laser enhances separation when used in conjunction with filamentation cutting techniques, such as Coherent's SmartCleave [1]. Filamentation relies on an ultra-short pulse laser to create a very high intensity, self-focusing beam within the glass. This ablates material along a thin (~1 µm) line, or filament, through the entire thickness of the substrate. These laser-generated filaments are produced close to each other by a relative movement of the work piece with respect to the laser beam, essentially creating a perforation.

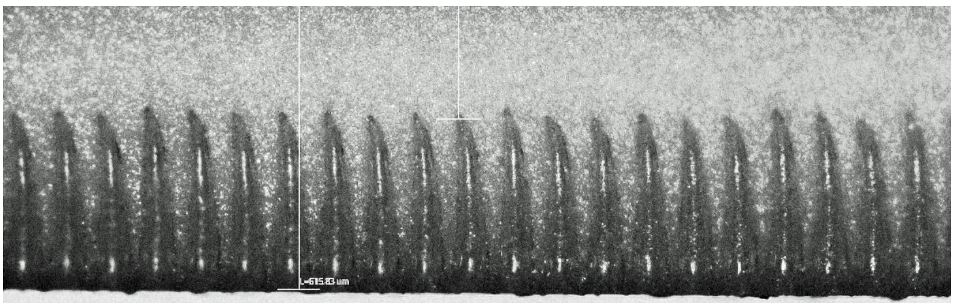

Figure 2: 40 µm width, 300 µm deep scribe in 0.64 mm thick fired ceramic. Scribe has an aspect ratio of >8:1 (depth/diameter), which is twice what can be achieved with CO2, and also shows no charring.

The CO laser is then used to provide the thermal shock necessary for separation. It was demonstrated the CO laser provides a much wider more robust operating process window as well as the capability to separate these glasses at higher speeds than possible with CO_2 laser.

Ceramic cutting

The CO laser brings similar benefits to scribing ceramics, another material employed extensively in microelectronics fabrication. Specifically, the shorter wavelength of the CO laser penetrates further into the material than CO_2 laser light, and produces a smaller heat affected zone and less discoloration. The shorter wavelength again delivers enhanced focusability, which, in the case scribing ceramics, is used to increase the depth of focus. Together, these factors enable scribing of substantially thicker substrates than possible with CO_2 lasers (see Figure 1).

Testing at Coherent has proven that external modulation of the CO beam can further improve results. In particular, the use of an acousto-optic modulator to deliver a pulsewidth of 150 μs at a repetition rate of 1.6 kHz both reduces charring and increases scribe depth (see Figure 2). The net result is the ability to produce scribes with an aspect ratio of 8:1 (depth to diameter). Finer scribes, with cleaner edges and better separation translate directly into improvements in cost and quality for microelectronics applications.

PCB microvia drilling

The trend towards greater miniaturisation in microelectronic devices has an impact on printed circuit boards (PCBs), which need smaller via diameters. Specifically, hole diameters are trending down towards 20-50 μm from the current 60-80 μm produced using CO_2 lasers. The shorter wavelength enables the CO laser to readily reach via diameters down to about 35 μm (see Figure 3). Even when producing larger diameter vias, the CO laser has an edge over CO_2. Specifically, the focusing lens used to achieve a 70 μm diameter via with a CO laser has twice the focal length of the lens required to achieve the same via size with a CO_2 laser. This delivers greater depth of focus, which allows the scanner field of view to be increased. The longer focal length and increased depth of field also facilitate an increase in scanning speed, and therefore faster via production, with the shorter wavelength CO laser.

The most common polymers used for PCBs are FR4, a fiberglass and epoxy composite. The CO laser wavelength is well absorbed by FR4, enabling high efficiency drilling. Use of the CO laser with other materials depends upon their particular absorption characteristics. Most importantly, however, the CO laser wavelength is highly reflected by copper. This allows the drilling to automatically "self terminate" when the copper layer is reached, which is critical to the way in

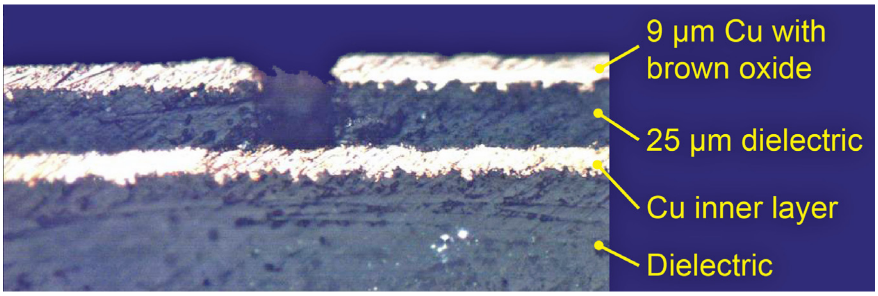

Figure 3: 30 μm via drilled in a commonly used PCB substrate with a CO laser

which laser via drilling is currently implemented.

Plastics film sealing

So called "multilayer barrier packaging structures" are widely used for food and medical product packaging. Specifically, these are plastic films in which two or more materials are laminated together to get an assembly which combines the various desirable properties of the individual materials, such as oxygen or moisture barriers.

In order to fabricate a package, such as a bag, two layers of these composite films are placed in contact and then heated until they fuse. CO_2 lasers are commonly employed for this purpose. These are available at several different output wavelengths around 10 μm, with the specific choice being highly dependent upon the exact absorption characteristics of the materials being used.

However, for one particularly popular film, which combines a thin layer of PET (Polyethylene Terephthalate) over a thicker layer of PE (Polyethylene), the CO laser offers a very attractive alternative. This is because PET, which is more mechanically robust and therefore used as the outer layer, is more transmissive at 5.5 μm than around 10 μm. For PE, the situation is exactly the opposite. This allows the CO laser light to penetrate through the PET and deposit most of its heat at the PE/PE interface (see Figure 4) where melting is desired. The result is that the CO laser produces a mechanically strong weld, with a smaller HAZ, at higher throughput.

Conclusion

The output characteristics of commercially available lasers have diversified tremendously over recent years. This makes it easier to match a laser with the exact requirements of a specific task. The CO laser offers a unique set of characteristics, making it an ideal tool for a number of different industrial processes. The CO laser will help enable future applications in the microelectronics, food packaging, and glass processing industries.

Reference

[1] Oliver Suttmann et al. Advanced Cutting Processes for Thermal Sensitive Materials – Composites and Glass, 13th International Laser Processing and Systems Conference (LPC 2018)

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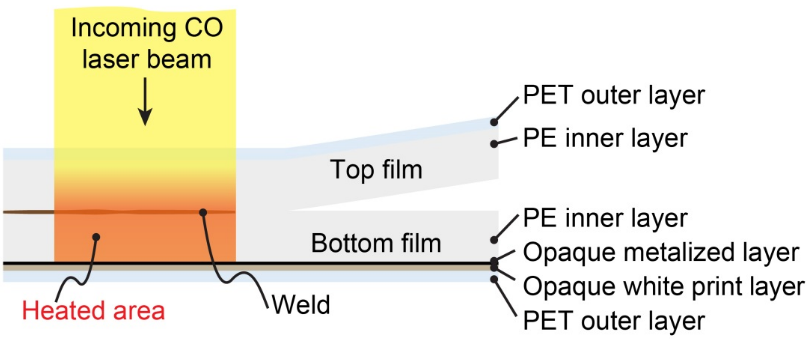

Figure 4: The CO laser readily passes through the outer PET layer and is well absorbed by the inner PE layers producing rapid melting and a strong, high quality seal.

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