

Wet Laser for Micromachining of Medical Devices

Introduction

Thanks to high speed and flexibility, lasers have become popular for material processing. However, due to heat damage and contamination, they are not perfectly suited for delicate micromachining. These drawbacks have been overcome a few years ago by combining a water jet with a laser beam, creating a totally new machining technology called water-jet-guided laser.

Water-Jet-Guided Laser

The new water-jet-guided laser process uses a low-pressure, ultra-thin water jet to guide a laser beam by total internal reflection at the interface between air and water. The laser beam is focused into a nozzle while passing through a pressurized water chamber. The water jet emitted from the nozzle then guides the laser beam onto the work piece (see Figure 1).

Contrary to dry lasers, using a water jet prevents the formation of a heat-affected zone, since the continuous water jet cools the material between the laser pulses. Negative heating effects, such as structural changes, micro cracks, oxidation and thermal deformation, are eliminated. The second significant advantage of using a water jet is efficient removal

of the molten material from the cut. Because of the high levels of kinetic energy, the water jet is much more efficient than a gas stream. The few remaining particles cannot attach to the work piece as in dry laser cutting, as a thin water film is generated on the work piece surface to prevent contamination.

Because lasers have a conical shape above and below the focal point, when using dry lasers the working distance is short and controlling the focus is paramount. A tapered angle appears between the cut walls. When the laser beam is focused into the water jet, the beam below the nozzle becomes cylindrical, producing parallel walls. In addition, the

working distance is increased (up to several centimeters), eliminating the problem of focus control, as well as the cutting depth limitation (see Figure 2).

Different lasers can be used, offering a large choice of wavelengths, powers and pulse durations, to adapt the process to a wide range of applications. Pure de-ionized filtered water, pressurized between 100 and 500 bars (depending on the nozzle diameter) is used. The jet diameter, which depends on the nozzle used, can be comprised between 20 and 150 microns. Water consumption is very low and as there is no tool wear, the hourly running costs are kept low.

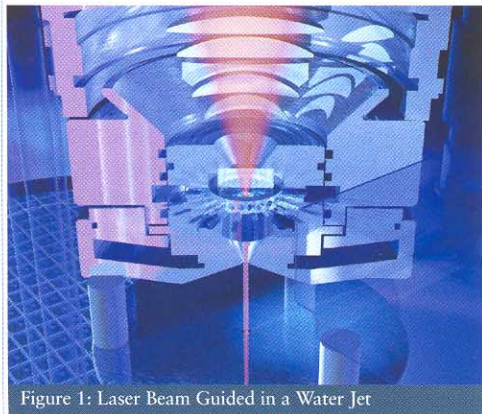


Figure 1: Laser Beam Guided in a Water Jet

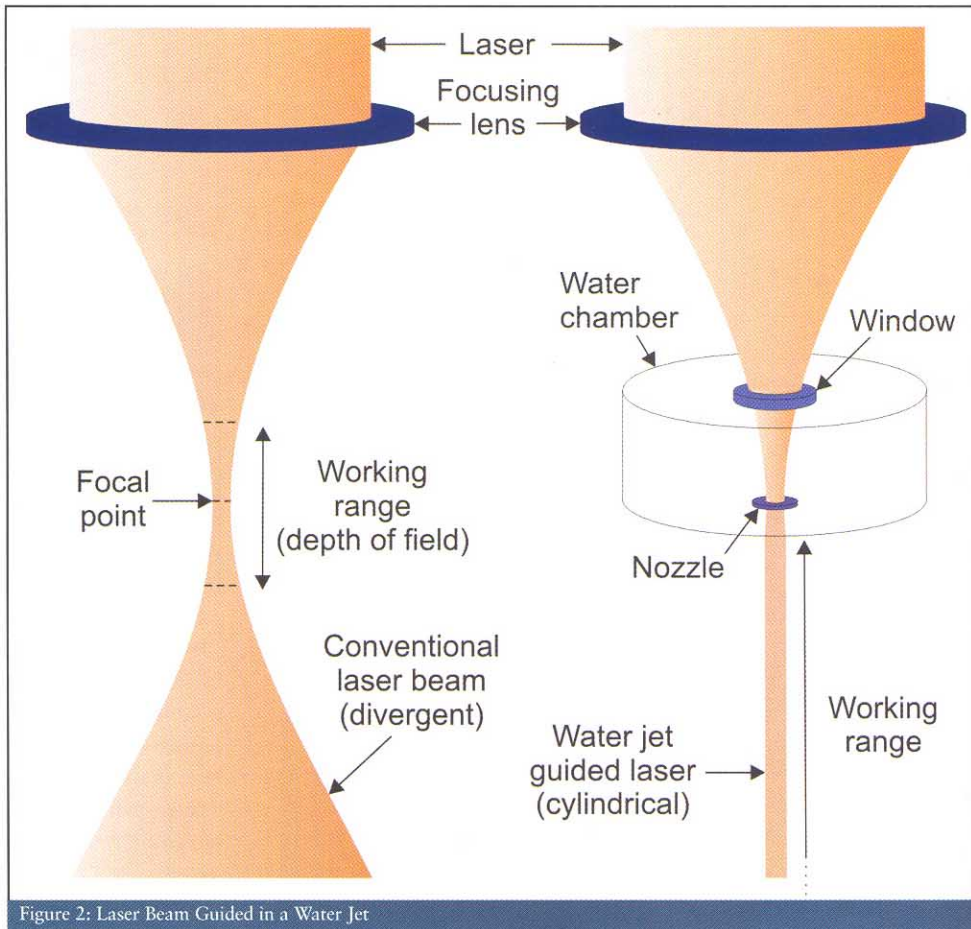


Figure 2: Laser Beam Guided in a Water Jet

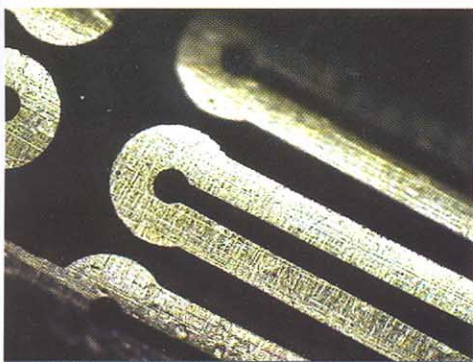


Figure 3: Nitinol Stent Cut by Laser-Microjet (detail)

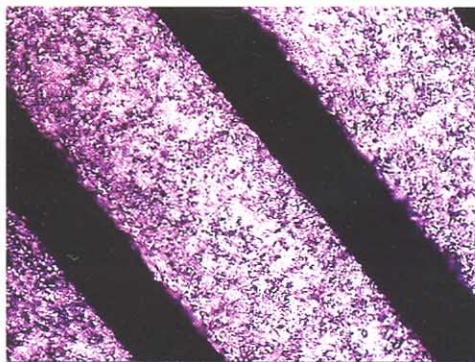


Figure 5: Grooving in a Piezo-Electric Material

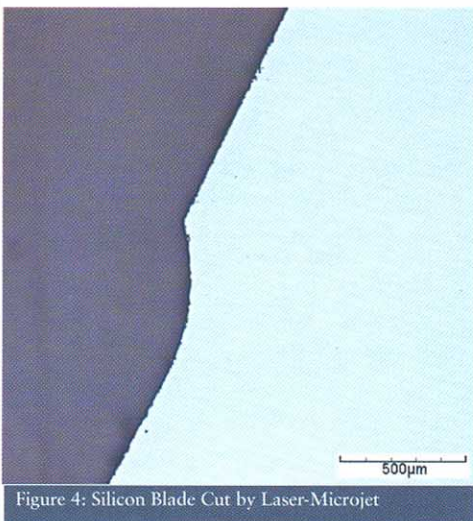


Figure 4: Silicon Blade Cut by Laser-Microjet

For several years, the water-jet-guided laser technology has been adapted to the manufacturing of medical devices such as blades and needles. One of its most promising applications today is stent cutting.

Stent Cutting

Stents are mesh tubes made of stainless steel, shape-memory alloys or polymers. The tube diameter is typically a few millimeters (between 0.5 and 2 mm), with a wall thickness between 100 μm and 200 μm . Cutting this fragile and complex structure requires high precision and as little damage as possible. The edges should be clean, with neither attached dross nor burrs, and the material should contain no micro cracks after the cutting process, so as to minimize the post processing steps.

A common process for stent manufacturing is laser cutting. Compared to dry laser cutting, the surface finish is significantly improved after Laser-Microjet processing, with

virtually no burrs along the cut edges and no oxidation caused by heat, thanks to water jet cooling. The absence of mechanical and thermal damages ensures that no cracks are generated in the edges during cutting, thus improving the stent strength. Time-consuming post processings can be reduced, increasing productivity. Etching produces high surface quality but is an expensive process and has limitation, as it can produce flat pieces but not small tubes.

Figure 3 shows a detail of a Nitinol stent cut by Laser-Microjet. The stent diameter is 2 mm and the wall thickness is 210 μm . An infrared laser (wavelength 1064 nm, average power 19 W) was coupled with a 38- μm thin water jet, to achieve an overall speed of 12 mm/s.

Accuracy of the axis and the vision control system of the Laser-Microjet machine ensure cutting precision and consistency. On the rotary axis, the tube is maintained inside a tubular plastic fixation to avoid damages to the processed part. In addition, while cutting, a water jet with controlled flow is generated inside the stent to stop the laser and thus prevent it from damaging the inside of the stent. Dry lasers obtain a quality far behind that obtainable with the Laser-Microjet, especially in Nitinol. Conventional lasers produce so many burrs that the cut edges stick together and only time-consuming post-processing steps can repair the laser-induced damages.

Silicon Cutting

Many devices for the medical industry can benefit from the water-jet-guided laser technology. Another example is silicon surgical blades. Due to the specific shape of the blade contour (see Figure 4), abrasive saws cannot

be used as they can only produce straight lines. For the particular example shown in Figure 3, the external contour and slots for fixing the blade have been processed by the Laser-Microjet, while the blade cutting edge has been achieved by etching.

Piezoelectric Materials

A third application example for the water-jet-guided laser in the medical device industry is the cutting of piezoelectric (PZT) materials, which are ceramics used for ultrasound devices. Any shape can be produced, without thermal effects or contamination. Figure 5 shows a visible grooving in PZT, 600-micron deep. There is no damage and the cut edges are clean. The material structure and composition has not changed in the cut edges.

Conclusion

Since its creation more than ten years ago, the water-jet-guided laser has been regularly adapted to new applications and has extended its activity to many state-of-the-art industries, such as semiconductors, electronics, energy and tooling. This versatile process can indeed process a wide range of materials, from thin to thick and from scribing to through cutting, this without damages to the material. It is therefore the most adapted machining process for delicate operations such as cutting Nitinol.

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