

"Dry" laser against "wet" laser - who will win?

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Abstract

Significant dissimilarities exist between the water jet guided laser technology (the "wet" laser), where a water jet guides a laser beam by total internal reflection at the water/air interface, and conventional "dry" lasers. In dry laser cutting, the working distance is short (conical beam shape). Heat damages are important, and the assist gas is not sufficient to remove the molten material, which may adhere to the material surface. With the water jet guided laser, the working distance is much longer (cylindrical jet). Heating is negligible, thanks to the water jet, which also efficiently removes the molten material; the particles are washed away by water. This paper details these fundamental differences, which lead both technologies to different markets.

Keywords: water jet guided laser, laser cutting, damage-free cutting, clean cut

1 Introduction

Today, lasers are widely used for industrial micro machining, as they offer many advantages – such as free-shape cutting and high cutting speed. For the last several years, a new technology using lasers has been developed, which present important dissimilarities with conventional laser cutting. Indeed, this technology has the distinctive feature of using a water jet as a guide for the laser beam. Because of their differences, the two technologies are not employed in the same scope of application

2 Comparison between dry laser and wet laser

2.1 Shape of the laser beam

In order to generate a power density sufficient to melt and ablate material, lasers need to be focused. Thus, the depth of the field (area around the focal point where melting is possible) is limited – to no more than a few millimeters or even below (see Fig.1, left). Furthermore, focusing would also be needed with high-power, diffraction-limited lasers.

Guiding a laser inside a water jet creates an "artificial" parallel laser beam that is perfectly cylindrical (no diameter variations) in the context of its stable length. This length is about 1000 times the water-jet diameter (for example, 50 mm for a 50-micron water jet), which corresponds to a working area that is at least 100 times longer than is the case with conventional lasers (see Fig.1, right). As the work piece can be placed anywhere inside the stable length, focus-distance control is unnecessary. Consequently, the cutting depth is increased (porous or sandwich structures can be cut), the cutting edges are totally parallel, and corrugated materials can be cut easily.

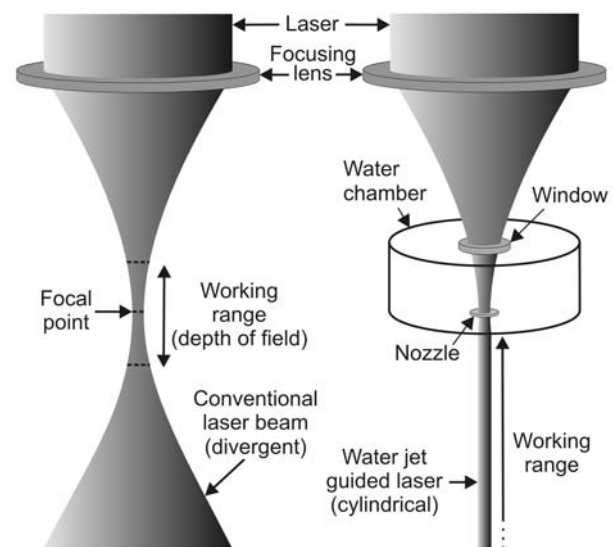


Fig. 1: Beam shape: conventional laser (left) and water jet guided laser (right)

2.2 Heating

When using lasers, material is molten and ablated through absorption and a consequent heating process. In continuous-wave mode, the thermal load in the material is very high, which make this kind of lasers unusable for precision processing. Pulsed lasers reduce thermal load; however, each pulse deposits additional heat into the material (more than is necessary for material removal). This heat, which is not cooled by the assist gas, is conducted into the material, subsequently generating a heat-affected zone (see Fig.2). Using lasers with short wavelengths and short pulses reduces this effect. The heating effect is eliminated with ultra-short laser pulses, which produces photo-ablation. However, photo-

ablation is a very slow process and can never be applied for volume production.

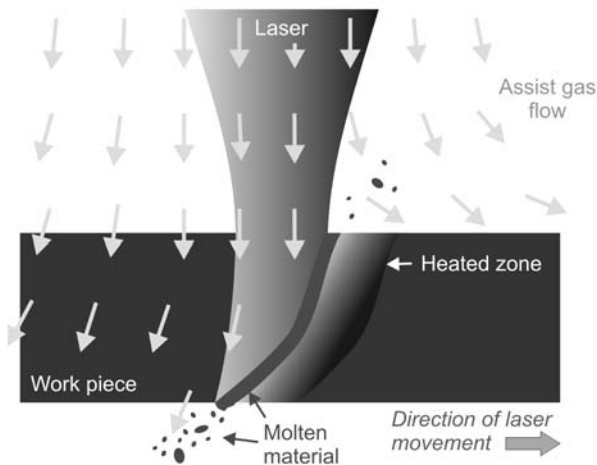


Fig. 2: Conventional laser cutting

2.3 Material removal

After heating, the liquid (or gaseous) material has to be removed. In conventional laser cutting, this task is performed by an assist-gas stream with limited pressure (max. 20 bars). This gas stream is not very efficient, since only a small part of the gas penetrates into the kerf and the kinetic energy is low.

When Laser-Microjet technology is used, all the water is used to remove the material; furthermore, the water jet involves very high levels of kinetic energy (see Fig.3). Removal by water is thus about 800 times more efficient than by gas. Because the water jet is very thin (with a typical diameter ranging from 75 to 25 microns), the force applied on the work piece is much lower than the force generated by the gas stream, even at high water pressure values (which can reach 500 bars).

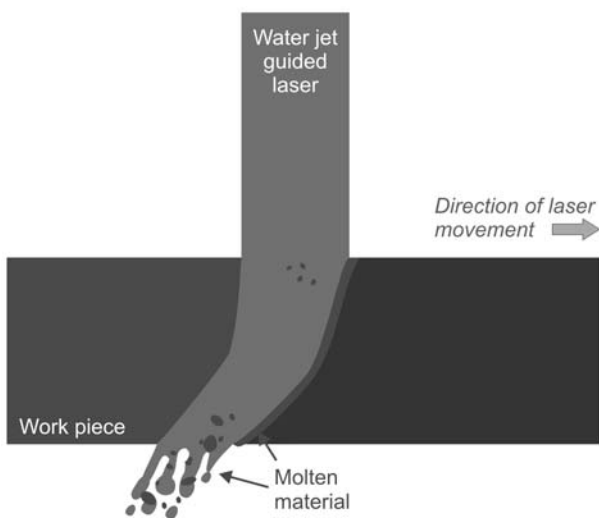


Fig. 3: Water jet guided laser cutting – material removal

2.4 Contamination

Once the molten material is removed, particle deposition on the work-piece surface (contamination) should be avoided. In conventional laser cutting, part of the molten material is deposited onto the surface. The only way to completely avoid these deposits is to add a protective coating during the cutting process and subsequently remove this coating. Because two additional steps are required, this solution is not practiced.

With the water jet guided laser, if most of the molten material is removed by the water jet, only a small amount of particles remain. To avoid any deposits a thin film of water is generated on the surface of the work piece. Particles that fall onto the film are immediately cooled down and cannot adhere to the surface of the work-piece (see Fig.4).

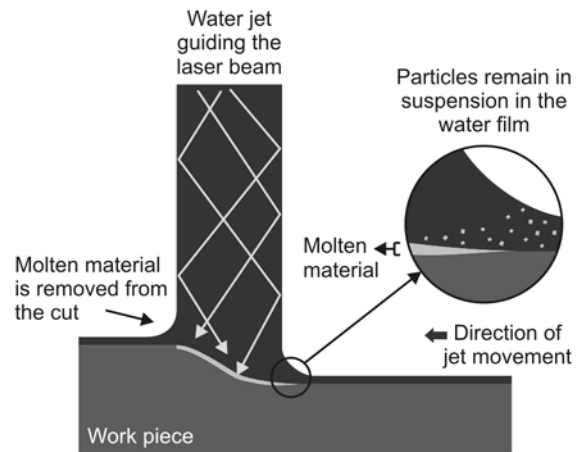


Fig. 4: Water jet guided laser cutting – material removal

2.5 Drawbacks of the water jet cutting technology

The water jet guided laser is a versatile process – but not universal. Due to the water jet, the Laser-Microjet may be delicate to use in some cases. First, the fact that the Laser-Microjet is a wet process may entail problems with some materials that are water-sensitive. The processed pieces need to be dried after the cutting process.

A wide range of materials can be processed using the Laser-Microjet; however, materials with low absorption coefficient values such as copper are difficult to cut because they do not absorb the laser light efficiently. Conventional lasers heat the material and increase the absorption coefficient in this way, allowing cutting of low-absorption materials. For example, the Laser-Microjet can cut copper up to 150 microns thick, whereas conventional laser cutting can produce 1-mm cuts in the same material. Drilling of high aspect ratio holes can also be problematic because water has to be evacuated; therefore, the aspect ratio is limited (around 1:1); in dry laser drilling, the ratio is 1:20.

Cutting machines have to be designed for water environment. Machines using the Laser-Microjet technology require additional equipment such as a water pump. Finally, due to the liquid jet, mirrors cannot be

used to deviate the jet; consequently, the table or the cutting head should be movable.

3 Conclusions

Dry laser and wet laser are fundamentally dissimilar processes. Because both technologies have different characteristics, the two approaches are not used in exactly the same scopes of application. Conventional lasers are efficient for thick metal cutting, drilling of high aspect ratio hole and marking. For applications requiring precision and no damage at all, the water jet guided laser is a more suitable process, and it is mainly used for grooving and cutting. Examples of potential markets for the Laser-Microjet technology include thin wafer dicing, stencil cutting, and medical stent cutting.