New Micro-machining Possibilities with the UV Microjet®

"Published in German in the March issue of Laser Magazin Deutschland."

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Industrial components, especially in the electronics industry, are becoming smaller and smaller. The market for the applications requiring micro machining technologies is growing fast and new capabilities are being explored. A promising collaboration is now announced between Synova SA, Switzerland, inventor of the Microjet® and Lambda Physik, Germany. Synova is the well-known laser manufacturer for the development of a cutting and surface treatment system using a UV laser guided through a water jet.

Cutting with laser and water?
The laser beam is focused in a nozzle while passing through a pressurized water chamber (see Fig. 1). The water jet emitted from the nozzle guides the laser beam by means of total internal reflection at the water-air interface, in a manner similar to conventional glass fibres. The water jet can thus be referred to as a fluid optical wave-guide of variable length.

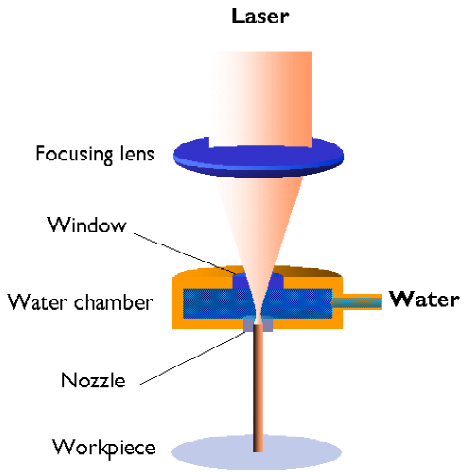

Fig. 1: Microjet® Principle.

The water jet is essentially transparent for the laser beam. However, if the laser beam encounters a body, which absorbs it, the surface of the material is heated to such an extent that plasma is created. The plasma separates the water jet and the material from one another and efficiently couples the energy to the workpiece.

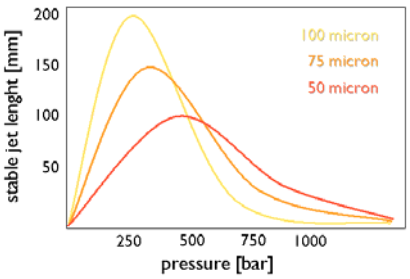

Fig. 2: The stable jet length is measured from the nozzle inlet to the position where the first drop is formed. The maximum working distance of water jet guided laser cutting is closely correlated to this value and varies analogously concerning nozzle diameter and pressure.

The plasma only remains as long as the laser beam is activated. Because a pulsed laser is used, the continuous water jet is able to immediately cool the cutting kerf, resulting in a strongly reduced thermal load of the workpiece.

The liquid used is deionized, filtered water.	
water pressure	20-500 bars
water jet speed	up to 300 m/s (at 500 bars)
water jet diameter	40, 50, 60, 75 or 100 microns
water flow rate	5-100 ml/min

Table 1: Characteristics of the water jet.

Applications for the Microjet Technology
The technology for a water jet guided laser, using an infrared laser, has fast proven efficient in different industries. The main advantage of the system is its excellent cutting quality obtained because of:

- the absence of thermal stress, and contamination burrs due to constant cooling and rinsing by the water jet.
- the absence of mechanical constraints on the pieces to be cut, the water jet pressure being kept low (50 to 500

bars with a jet diameter varying from 50 to 100 microns).

For example, in the electronics industry, the main applications are cutting of stencils for PCB fabrication or realization of precise ferrite cores gaps.

Outstanding results are also obtained in the cutting and drilling of hard material such as Cubic-Boron-Nitride or synthetic diamonds for the tooling industry where other standard methods such as electro-erosion are quite inefficient.

In the medical domain, applications range from cutting of stents to manufacturing of blades for ophthalmic surgery. One of the actual key applications is the cutting of chips out of silicon wafers. The usual cutting technique for silicon wafers is sawing. The introduction of a laser allows the production of new shapes and different chips sizes on the same waferThe system has proven the highest efficiency when cutting thin wafers (thickness below 100 microns) because of the constant cooling and high cutting speed.

The electronics industry evolute fast and is very demanding. New opto-electronic devices use glass on silicon or silicon on glass, but a water jet guided infrared laser is almost impotent in terms of cutting transparent materials.

Why develop a UV-Microjet®?

Until now, the technology has only been used with infrared and green lasers, thus limiting the range of applications to materials with a sufficient absorption coefficient to these wavelengths. It was therefore very difficult, or even impossible, to cut transparent materials (glass, diamond, sapphire, transparent polymers). The idea came about to adapt a UV laser, known for its better absorption coefficient in transparent materials, to the Microjet® technology.

Synova SA and Lambda Physik decided to collaborate for the development of this new tool. In a first step, a feasibility study will be made with a standard UV PowerGator 355-10 (see Table 2). A setup adapted to the UV wavelength has been built, using quartz and CaF_2 lenses.

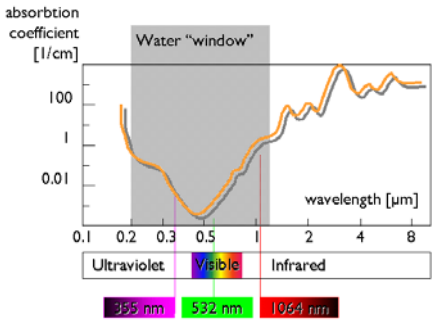

Fig. 3: Water absorption coefficient.

The questions to be addressed will then regard the water jet. Indeed, the theory shows that useable wavelengths are limited to the range in which the absorption by water is low, which means with an absorption coefficient below 1/cm (see Fig. 3). The UV is comprised in this window, but no practical tests at high intensity have been done so far.

PowerGator 355-3	
Wavelength	355 nm
Average Output Power	10 W
Pulse Energy	1 mJ
Pulse Duration	15 +/3 ns

Table 2: Specifications of the UV laser.

Microjet® machines are designed to be modular. The laser source is therefore connected to the cutting head through an optical fibre. To prevent damage to the fiber, a core diameter of 100 microns is used for a water jet of 50 microns diameter.

In a second step, a new UV laser with optimized parameters for the Microjet® will be introduced. Changes will be made probably regarding pulse repetition rate, pulse duration and average power.

New Capabilities and Applications

The introduction of the UV laser should introduce new cutting possibilities regarding transparent material, as well as smaller water jet diameters.

Until now, the standard use of an infrared multi-mode laser rendered difficult the use of very small nozzle for the water jet because of the necessary size of the focus the expanded laser into the water jet. But since the PowerGator UV laser is mono-mode the focus area promises to be much smaller, allowing the use of a water jet of

less than 50 microns in diameter. This improvement will allow cutting kerfs down to a width of 20 microns.
About new capabilities regarding materials, cutting or scribing of transparent materials such as polymers, glass, diamonds, sapphire, are promising applications.
For the semiconductor industry for example, a UV laser can cut silicon wafers covered by a layer of glass or diamond. This kind of material is now commonly used for the production of fast opto-electronic components. The results may also be promising for the electronics industry, since the presence of glass or Kevlar® fibers in PCB, and especially flexible ones, used to make it difficult to cut with the standard MicroJet®.

The feasibility study of the water jet guided UV-laser, transmitted by a fiber is already proven. Beginning 2004, the UV laser for the Microjet® will be choosen. Commercial machines with a UV-laser will be available from middle of 2004 on.