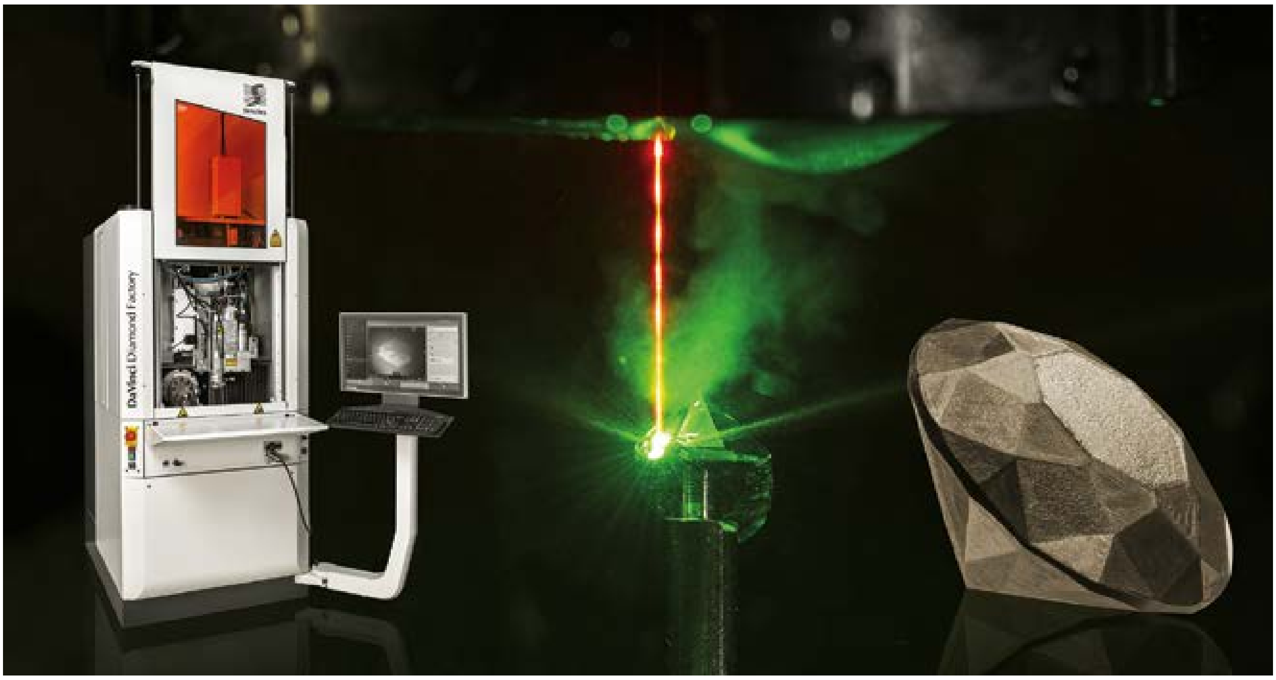
Gentle to the material, precise, and fast

Precision processing of high-tech materials using a water laser



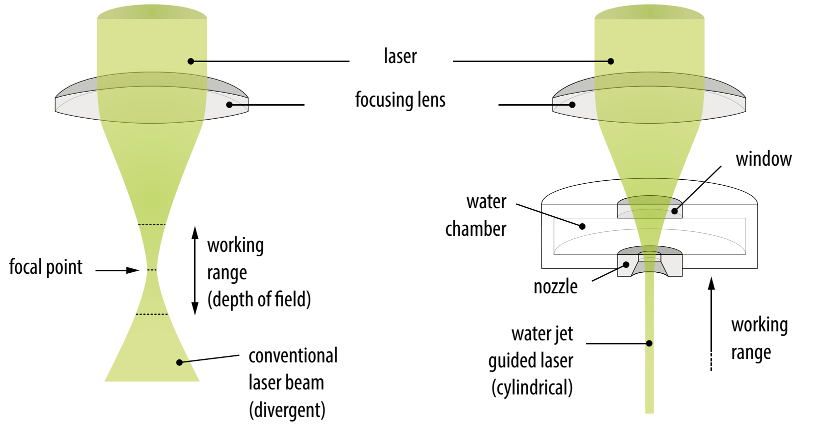
In the patented LMJ technique, the processing is carried out by a water jet as thin as a hair through which high-energy laser impulses are directed. The water cools the workpiece in the process and prevents damage to the material. This method is being used in ever more applications, and in particular for materials that are hard to process, such as hard metals, cubic boron nitride (CBN) or diamond as well as all types of ceramics. It is also just as suitable for fiber-reinforced composites, titanium, cobalt and superalloys or semiconductor materials. Here are some current applications.

"The fundamental difference between our Laser MicroJet (LMJ) method and other laser techniques is the guiding of the laser beam down the inside of an inherently stable water jet as thin as a hair," says Dr Amédée Zryd, director of applications, research, and development at Synova in Duillier/Nyon, Switzerland. The high-energy nanosecond laser pulses are coupled into the water jet, which is only a few dozens of micrometers wide, with the help of a sophisticated optical head. The water has exactly the same purpose as the optical fibers in communications cables whereby the laser light is internally totally reflected at the boundary of the water to the air. In contrast, the working range of a conventional laser system is very short because of the focusing that is done by lenses. This characteristic of LMJ lasers enables very deep cuts with true vertical, very smooth surfaces. The medium pressure water jet – up to 500 bar – prevents thermal damage and at the same time washes away any reaction residue from the workpiece. The result is clean surfaces as well as material characteristics that correspond to those of the material before processing. The thin water jet permits extremely narrow and absolutely parallel clearances of 25 – 80 µm with only minimal roughness.

▲ The DaVinci Diamond Factory is a complete turnkey solution for the faceting of diamonds (Source: Synova)

Applications: tools, metal sheets and special alloys …

"An application of growing commercial interest is the processing of tungsten carbide and cutting ceramics such as CBN, SiC, aluminium nitride or alumina," says Dr Zryd. It is not only about the basic geometry, but ever more often about achieving five-axis geometries, such as the required cutting angle and the sharpness of edges in cutting tools.



While a water jet guided LMJ laser remains focused over a long distance, the intensity of a conventional laser beam drops off quickly beyond the point of focus (Source: Synova)

A further promising application has arisen from the manufacture of permanent magnet materials such as NdFeB, which can only be processed with difficulty because of their hardness and brittleness. Synova can help here because the technique also allows thick materials to be processed. In addition, there is virtually no effect on the magnetic properties of the material because of the excellent cooling provided by the water jet. Further interesting applications of the LMJ technique include the drilling of cooling holes in ceramic-coated turbine blades as well as in large silicon components that are used in wafer reactors as consumables.

> The focusing of the laser light within a stable water jet enables very deep cuts with vertical and very smooth surfaces
>
> Dr Amédée Zryd


Synova

In this last case, specially constructed systems were developed for a large customer. According to Dr Zryd, a number of these systems are now in use there almost the whole year round in three-shift operation and have reached an uptime of 98 %. This confirms the maturity of the LMJ technology to carry out work that meets the highest requirements of quality and reliability while meeting strict safety standards.

… diamonds …

“Although clear diamonds hardly absorb our green laser light, we are still able to process diamond materials,” discloses Dr Zryd. The reason is simple: black graphite is formed on the surface of the diamond as soon as the first laser beam hits it, which absorbs the following laser impulses very well. The thin graphite layer can be easily polished away afterwards. One of the important advantages of the Synova technology here is the narrow cutting width because only very little of the expensive stone volume is lost. There are special solutions for the jewellery industry, such as the DaVinci Diamond Factory which machines rough diamonds into fully facetted brilliants.

Artificial diamond stones made by the CVD process are a growing application where such lab grown crystals are cut by laser into monocrystalline slices. The depth of the cut is continually increasing: the standard currently lies at about 10 mm, although 20 mm has already been achieved. As the workpieces can be turned and worked on from the rear, slices with a depth of up to 40 mm can be created. Other industrially-produced diamond materials like MCD, PCD or metal-matrix diamond composites can also be easily machined.

… as well as fiber-reinforced composites and ceramics

“We are also able to process almost any type of ceramics or ceramic-composite, as long as it is not transparent to green light,” says Dr Zryd. There are currently some interesting developments on the subject of non-oxide (such as SiC-SiC) or oxide-oxide ceramic matrix composites

Company

Synova

Synova SA, headquartered in Duillier, Switzerland, develops and manufactures advanced laser cutting systems that incorporate its proprietary water jet guided laser technology (Laser MicroJet) in a true industrial CNC platform. Customers benefit from significant yield and improved cutting quality as well as enhanced capabilities for precision machining a wide range of materials. The company has supplied over 400 machines designed for applications such as drilling coolant holes in turbine blades, faceting rough diamond stones and processing semiconductor materials.

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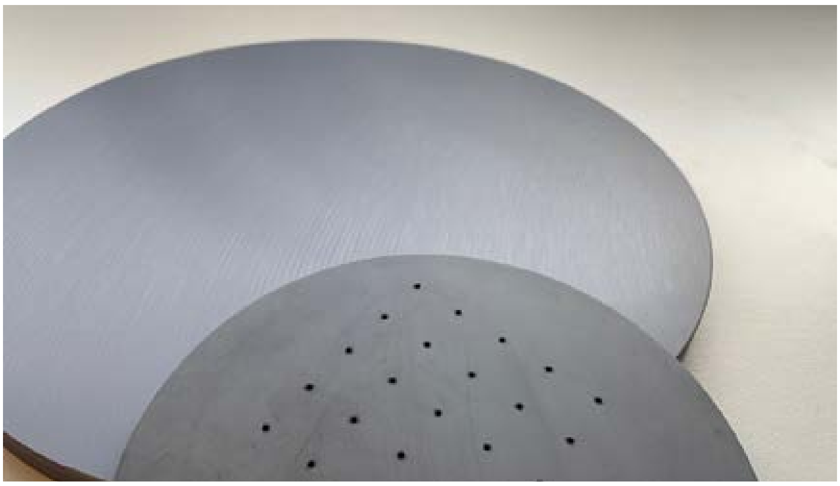
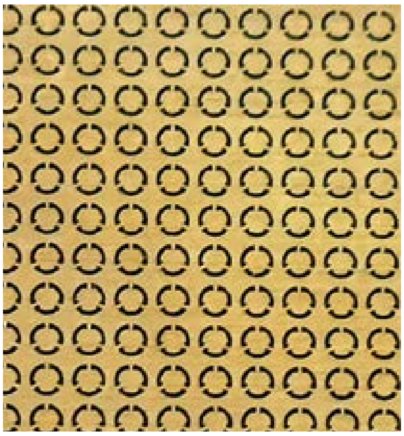


Holes are made in these discs of high purity silicon using the LMJ technique to let gas through during the production of wafers (Source: Synova)

Numerous openings to the hollow interior of the blades in modern gas turbines provide cooling for the blade surface (Source: Synova)



A spinneret structure in a thin metal sheet (Source: K. Vollrath)

(OxOx-CMCs). These materials consist of high-grade ceramic fibers embedded in a ceramic matrix. They are primarily used in aerospace because of their excellent thermal resistance with good high temperature strength and low weight, and compete with titanium materials and other high-temperature alloys. Equally easy to process are carbon fiber composites as well as numerous other ceramic materials, some of a particularly complicated composition, that are used in the production of power semiconductors or sensors, as well as diamond grained composites. These consist of diamond grains embedded in a metal or ceramic matrix and are used in contoured grinding wheels or watch cases that display high resistance to scratches and other damage through the diamond grains. The semimetal silicon and the ceramic silicon carbide are also of growing interest. An example of an application is for solid silicon discs up to 10 mm thick. These are drilled with precisely placed and dimensioned holes for the production of silicon chips. An exact amount of an aggressively reactant gas is fed through these holes onto the wafer.

Micro and macro-processing

"A further advantage of our cutting technique is the ability to create high-precision microstructures", says Dr Zryd. An example of these are so-called spinnerets, which are spinning nozzles for the production of textile fibers. These structures consist of arrangements of very small openings through which thin strands of liquid plastic are extruded.

The plastic polymerises as it exits and forms the required textile fiber. Whole bundles of thin fibers can be created through the appropriate layout of such spinnerets that are then combined into a thread. The LMJ process is ideal for creating these structures as the openings and holes have very clean edges and smooth, exactly vertical sides. This is important to ensure the faultless quality of the fibers. On the other hand, the LMJ technique can also be used to create large structures with extremely thin, sometimes only 30 µm wide poles e.g. for vibration sensors. With regard to the area of the workpiece, there are no real limits for the LMJ method. For example, it would be in principle possible to fit an optical head onto a robot arm for remote machining.

Highly reliable process technology

"We have to monitor numerous parameters during long periods of operation and keep them stable to ensure reproducible results," adds Dr Zryd. The workpieces are, after all, often very expensive. So Synova has developed a number of solutions over the years and, thanks to this perfecting of the technique, LMJ systems can maintain high uptime levels even under continuous operation.

There are standard systems available in three or five-axis versions with a working volume of 50 × 50 × 50 mm up to 690 × 630 × 100 mm. Larger gantry systems are also possible. To handle the variety of usage scenarios, there are numerous specialized versions for particular applications, such as diamond machining, the shaping and grinding of cutting edges, the drilling of cooling holes in turbine blades or the processing of semiconductor materials for computer chip manufacture.

As with every other groundbreaking development, the LMJ technology is also

These filigree structures were cut from a thick sheet of silicon carbide using the LMJ technique (Source: Synova)

being illegally copied ever more often. Synova's fundamental developments are patented and well protected by around twenty patent families with a total of some one hundred individual patents. "We are following developments in the market very closely and will act rigourously against any infringement of our intellectual rights," confirms Dr Zryd.

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Text: Redaktionsbüro Klaus Vollrath, Aarwangen, Switzerland, b2dcomm.ch

Further reading: *N. Shankar:* The First Coupling of a Laser Beam to a Water Jet – How a miniature dental hand tool started a revolution in cool laser machining, PhotonicsViews **18**(1), February/March 2021, pp. 72–76; DOI: 10.1002/phvs.202100014

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