Laser water jet cools and cuts in the material world

After 10 years in the making, Synova's water-jet-guided technology is being used to cut, drill, grind and dice materials as varied as gallium arsenide and polycrystalline diamond. **Jacqueline Hewett** catches up with Synova to find out the advantages of the approach.

The micromachining market is already crowded with sources such as solid-state and fibre lasers vying to supplant traditional methods. One company backing a different approach and hoping to capture a significant market share is Synova, which is pioneering water-jet-guided laser technology.

Synova is confident that its patented LaserMicroJet technology, which involves directing a laser beam into a thin water jet, has a number of significant advantages over classical laser cutting such as: no heat-affected zones, parallel kerfs and the ability to cut thick and hard materials (see box p19).

And it seems that the industry is starting to take note when you look at the firm's track record over the last nine months. On the back of CHF10 m ($8.1 m) of venture capital funding received in August 2006, Synova has opened two US micromachining centres (MMCs) in Boston and Silicon Valley to promote its technology and fuel its adoption. MMCs are also scheduled to open in Korea and Japan in March.

In terms of orders, Vishay, a maker of discrete semiconductors and passive components, placed a follow-on order in September 2006 for a laser-dicing system. Then in January, Synova secured two orders from Korea – one for a stencilling system that will be used in OLED mask manufacturing, and the second for a system that will perform thin-wafer edge grinding.

All images: Synova

Synova has exploited the advantages of its LaserMicroJet technology to produce clean and parallel cuts in a range of materials. The images here show the cutting of marble (top left), OLED masks (top right), medical stents (bottom left) and cubic boron nitride (bottom right).

Wet cut versus dry cut

Synova was established in 1997 with the aim of commercializing the water-jet idea developed by the firm's founders in the early 1990s at the Federal Institute of Technology in Lausanne, Switzerland. Today, 10 years later, the firm has 60 employees and subsidiaries in the US, Japan, Korea and China.

"The original technology was developed to decrease heat damage during laser dentistry," Tuan Mai, Synova's director of process development told *OLE*. "But we soon realized that using a water jet opened up new applications for industrial laser machining thanks to its many advantages over traditional techniques."

The basic idea is simple: take one laser beam and couple it to a pressurized water jet. This sounds good in principle, but as light and water are not natural bedfellows, it is easier said than done.

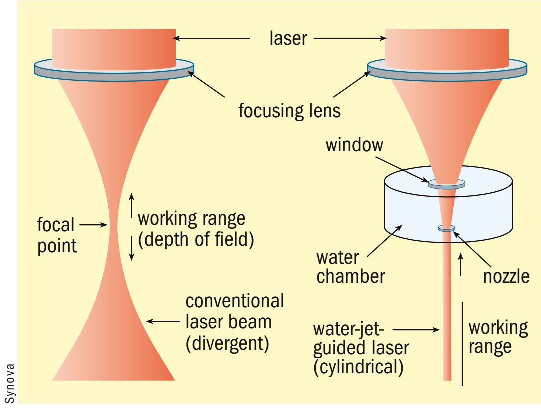
Synova's key technology is a coupling unit (see diagram p18) that forms the heart of its modular LaserMicroJet product line. The unit passes a laser beam through a water chamber where it is focused onto a nozzle. The laser is then contained inside a water jet by total internal reflection and guided to the workpiece where it ablates material by heating. The water jet cools the workpiece between laser pulses and expels molten material from the cut.

In comparison, during dry laser cutting, the laser is focused directly onto the workpiece, and the beam has a conical shape between the focusing lens and the focal point. The beam ablates the material by heating at the high-intensity focal point. An assist gas, coaxial to the laser beam, removes molten material.

Each LaserMicroJet product has three key separate components: a laser source, a water pump and a coupling unit.

The laser is typically a pulsed solid-state source such as an Nd:YAG emitting at 1064 nm, or a fibre laser emitting at approximately 1070 nm. "The absorption properties of water at different wavelengths dictate the choice of laser," explained Mai. "For example, you cannot use a CO_2 laser with our technology because the water absorption is so high you would boil the water. However, you can use a second harmonic at 532 nm and a third harmonic in the ultraviolet at 355 nm."

Average laser powers can range from 50 to 200 W; pulse durations from the nano- to microsecond scale and pulse repetition rates from 500 to 50 kHz depending on the pulse duration. The laser source can be remote from the machining system as



The diagrams on the left compare a dry (left) cut using a conical beam and a water-jet (right) cut using a parallel beam. The instrument on the right is a Synova laser-dicing system.

a flexible 100–200 µm-core-diameter fibre delivers the beam into the coupling unit.

"This means that we can use multimode lasers and don't have any problems with beam astigmatism," commented Mai. "The beam is homogenized inside the water jet and we see a top-hat profile that is very good for cutting. It also means that you can remove the fibre and plug it into a second laser if you want to test different sources."

The pump delivers a constant water flow with pressures ranging from 2 to 50 MPa. "The water must be clean and free of contamination and particles because we use the water jet as a waveguide, so it must be transparent and stable," said Mai. "We deionize and degass the water to ensure that there are no perturbations in the jet."

In the coupling unit, Synova uses a series of optics to image the end of the delivery fibre onto the water-jet nozzle. Made from diamond or sapphire, the nozzles are interchangeable and are available in diameters ranging from 25 to 150 µm.

Mai explains that in general, the working distance is 1000 times the nozzle diameter. This means that a 50 µm nozzle gives a working distance of 50 mm and a corresponding kerf width of 50 µm.

Synova's LaserMicroJet product line has four family members: dicing, edge-grinding, stencilling and cutting systems. "Today we mainly concentrate on so-called micro-applications. That is the niche for us at the moment," commented Mai. "Our technology can be adopted wherever a normal laser is being used."

According to Mai, one up-and-coming market is wafer dicing, which typically relies on diamond blades. The company has used its technology to successfully dice silicon, gallium arsenide and germanium wafers, as well as silicon carbide (SiC) and sapphire. Important advantages include the absence of a thermal load. The kerf can be close to the die to increase the number of chips per wafer and give a higher die-fracture strength.

Synova says that one of the most significant issues with dicing SiC wafers is blade wear – LaserMicroJet technology removes this worry and lowers the downtime and corresponding cost of ownership. Synova has demonstrated through-cutting of 380 µm thick SiC wafers with a kerf width of 45 µm and cutting speed 40% higher than a diamond saw blade (4.6 mm/s).

Another significant market where Synova has already seen some traction is manufacturing OLED masks. "We have been able to produce long and narrow slots with a tapered profile," said Mai. "In one example these were 55 mm long, 100 µm wide at the top and 50 µm wide at the bottom. The pitch between these can be as little as 150 µm."

Producing medical stents, which are used to open blocked passageways such as arteries, is another area where Synova believes its water-jet approach gives it the upper hand. "These are mostly manufactured using classical laser cutting and can require post-processing steps," said Mai. "Many stents are made from memory-shape materials such as Nitinol, which is very heat sensitive. Using a 30 µm nozzle, the pitch and size of the features can be made very small, and using a water jet avoids problems such as heating. There is no structural change in the material and no oxidation."

Finally, Mai believes that Synova is the only player that can cut hard materials with high quality, good/superior speed and high aspect ratio. Materials falling into this category include polycrystalline diamond on a tungsten carbide substrate and cubic boron nitride (CBN). "Using 532 nm light, an average power of 60 W and a water-jet diameter of 50 µm, we have cut 3 mm-thick CBN with a speed of 5 mm/s and produced a smooth, parallel clean cut with a sharp edge."

Boasting a list of advantages as well as a diverse range of applications, the technology, Synova believes, has what it takes to challenge all others in the materials-processing market. As the firm continues to expand and promote its technology, the term "water-jet guided laser" certainly looks like becoming more commonplace. □

LaserMicroJet facts

Synova believes that coupling a water jet and a laser beam together has revolutionized the field of precision cutting. The inherent differences between water-jet-guided and conventional dry-laser technologies are said to be responsible for the variations seen in the quality of the final cut.

Synova lists the following as advantages of its LaserMicroJet technology:

- The water jet removes heat between incident laser pulses and avoids the introduction of defects caused by heating such as oxidation or microcracks within the sample.
- The cut is exceptionally clean. Molten and condensed materials are washed away by the water. An additional thin water film generated on the workpiece prevents further contamination through redeposition.
- The ablation products are bound to the water in such a way that no hazardous materials (such as toxic gases) are emitted. This is an important advantage for dicing gallium arsenide wafers.
- The water jet exerts a low mechanical force on the workpiece (less than 0.1 N) – much smaller than the force that is applied by an assist gas.
- The diameter of the laser beam is determined by the diameter of the water jet. These conditions allow a cutting precision as low as 1 µm.
- There is no focal point between the workpiece and the nozzle. The quality of the cut does not vary with working distance.
- The water jet guides the laser down to the bottom of the kerf and high aspect ratios can be achieved during cutting. The cut edges are parallel.
- There is low water consumption of 1 l/h at 300 bars.