Cool Laser for Cutting Diamonds

Laser MicroJet combines the advantage of both laser cutting and water cooling in one operation

Nitin Shankar

Diamond cutters have been looking for a laser cutting tool that can slice through a diamond without causing any thermal damage.

Raw diamonds can contain inclusions in the form of non-diamond hybrid materials or air bubbles, making them susceptible to damage from intense heat during laser cutting. The heat of a conventional laser beam can cause the inherent material tension in such inclusions to explode the stone. Thus, a rough diamond worth several thousands of dollars can literally be reduced to worthless bits in a matter of seconds without any warning.

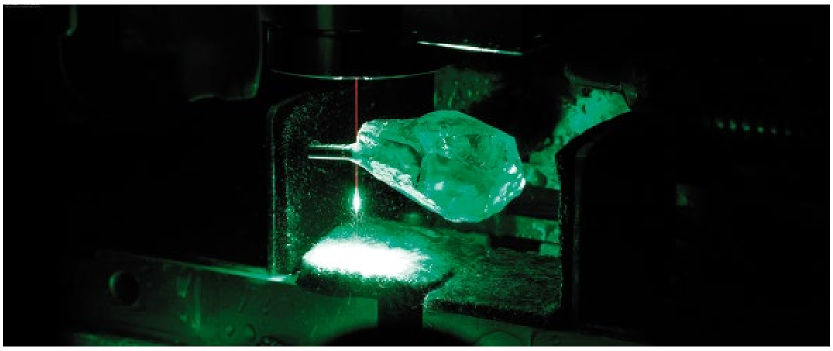

Fig. 1 Vertical laser beam cutting a diamond stone. (Source: Diamcad NV)

The advantages of combining laser and water

Unlike conventional laser cutting where thermal heating poses risks, the Laser MicroJet, between laser pulses, cools the surface of the stone with a water jet. This is effectively "cold laser cutting" and significantly reduces the risk of diamonds bursting due to laser heat (Fig. 1).

In the Laser MicroJet system [1, 2], a laser beam, passing through a pressurized water chamber, is focused into a nozzle (Fig. 2). The low-pressure water jet emitted from the nozzle guides the laser beam by means of total internal reflection at the water/air interface. The water jet-guided laser beam is parallel and its diameter, depending on the nozzle, can be 40 or 50 microns. The required laser power is less than 20 watts. While the principle looks simple, years of experimentation were required to fine tune the process.

As opposed to conventional 'dry' lasers, the Synova water-jet guided laser offers many advantages in diamond cutting.

With the water jet-guided laser, as already mentioned, there is a reduced risk of a rough diamond cracking when the laser beam hits a spot containing inclusions or air bubbles.

Another advantage of the water-jet guided laser is that it ensures a better surface finish. At the point where a laser beam strikes the diamond, the temperature can reach 2000 °C. In a conventional laser, the diamond's molecular structure is converted to carbon vapour on one pass of the beam and this carbon build-up is burned off on the return pass. Carbon debris adheres to the surface of the cut diamond. By contrast, the Laser Microjet uses the heat of the laser beam to cut while the water jet provides a cooling effect. As a result, the hot carbon vapour generated during cutting is constantly being evacuated by the flow of water resulting in a clean and smooth surface.

The parallel laser beam of the Laser Microjet provides a cutting depth of up to 50 millimetres. By contrast, a conventional focused laser beam has a limited working distance of just a few millimetres due to beam divergence. In a conventional dry laser, the beam converges at a focal point and then diverges. Therefore, a focus distance control is required and the working distance is short.

To meet the requirements of diamond cutters, Synova incorporated its Laser MicroJet into its above mentioned DCS (Diamond Cutting System) machines: DCS 300, DCS 150 and DCS 50 with table sizes of 300 × 300, 150 × 150 and 50 × 50 millimetres respectively (Fig. 3).

These machines are equipped with CNC (computer numerically controlled) controllers enabling the Laser MicroJet to cut the diamond along a predetermined path. The machine's optical head includes an optical fibre cable for laser beam transmission, a camera and a number of lenses. Due to its range of depth, cutting is achieved by the usage of one axis only, the horizontal *Y* axis.

Company

Synova SA
Ecublens, Switzerland

Synova SA manufactures laser cutting and dicing machines using its patented water jet-guided Laser MicroJet system. Founded in 1997, the company now has 60 employees and micro-machining centres in India, USA and other countries.

www.synova.ch

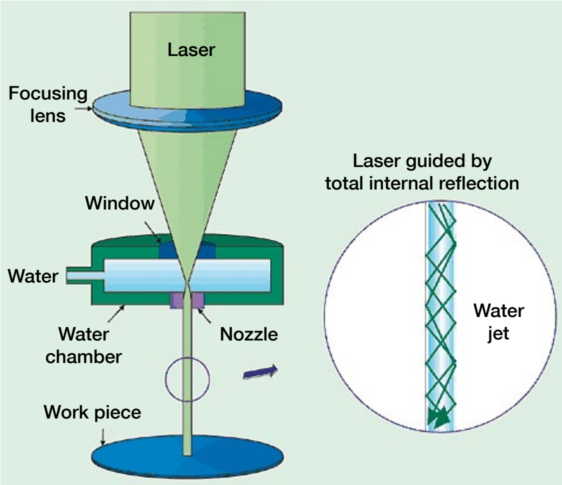

Fig. 2 Principle of water jet guided-Laser MicroJet

Surat – Cutting centre for small stones

Synova sold its first DCS 300 systems to diamond cutters in Surat, India, a town located 350 kilometres north of Mumbai that has pioneered in the use of laser technologies to cut diamonds.

Surat cuts and polishes nearly 85 % of all diamond stones in the world. These are mainly smaller carat diamonds. Almost a million people are engaged in evaluating, cutting and polishing diamonds in a city of nearly five million. There are more than 5000 laser systems in operation. While there are imported laser cutting machines from Belgium and Israel, there are also a high proportion of locally built laser machines.

The first customers were so-called "Sight-holders". These are companies that have a 3-year supply contract with the Diamond Trading Company (DTC), a sales division of De Beers [3], which is the largest supplier in terms of value of diamonds sold. Such diamond manufacturers, having a continual supply of raw stones, can keep laser cutting machines working on a 24 hour / 7 day basis.

Venus Jewel [4] is a typical example of such a Sight-holder company. More than 1300 employees work in its 8-storeyed, state-of-the-art centrally air-conditioned manufacturing unit in Surat, converting raw diamonds into polished gems. The company has a legacy of using cutting edge technologies and is focused on continually improving productivity in its diamond processing operations. After assessing the potential in the Laser MicroJet technology completely redefining the laser sawing process, Venus Jewel installed a Synova DCS 300, and Synova has adapted the machine to make it more suited not only to the industry's needs but customizing to Venus Jewel's specific requirements as well.

Synova also established its own subsidiary in Surat, starting with a DCS 300 system. Originally intended for demonstration and training purposes, the machine was soon busy cutting diamonds for smaller units. Soon a second system, a DCS 150, was added and the two machines now work on a 24-hour, 7-day basis. The operation employs 15 people and cuts up to 600 carats a day (Fig. 4).

Fig. 4 Synova micro-machining centre in Surat.

Fig. 3 Synova DCS 300 system

Due to the large volume of diamonds being cut, Indian processors are usually concerned about weight loss during the cutting process. Even when cutting small diamonds, the Laser MicroJet with its 40 micron parallel beam has an advantage over the typical "V" type shape cutting of conventional lasers. Therefore, approximately for a 3 carat stone, the weight loss during cutting is less than 1 %.

The extensive use of laser technologies in this industry in India has allowed smaller diamonds to be prepared as gems in greater quantities than previously economically feasible.

Antwerp – Cutting centre for large diamonds

While India handles large volumes of small diamonds, smaller quantities of larger diamonds are more likely to be handled in traditional diamond cutting centres in Antwerp, New York and Tel Aviv.

For a long time, diamond cutters preferred using mechanical saws, introduced in 1900, to laser machines for cutting larger diamonds. Although mechanical saws are much slower, the operator is in a position to detect signs of overheating when the phosphor-bronze blade, edge-coated with diamond powder and rotating at speeds up to 12000 RPM, approaches an inclusion. Thus, the risk of cracking diamonds during the cutting process is greatly reduced. However, cutting time may be measured in days or hours instead of minutes.

Diamcad NV [5], a reputed diamond company located in the heart of the diamond district in Antwerp, is operating its own DCS 300 system. The company has obtained a prominent reputation in the niche of large-sized high-value gem stones. Amongst its achievements, there is the historical 102 carat Graff Constellation which is the largest round diamond in the world and the 603 carat Lesotho Promise, the 15th largest rough diamond ever found, which was transformed into 26 finished gems.

The Synova DCS machines are particularly suited for cutting large diameters. Unlike conventional dry lasers, the water jet-guided cylindrical laser beam has a working distance of up to 50 millimetres, allowing big diamonds to be cut in a single operation without changing settings.

The laser appears in the form of short pulses that strike the surface of the diamond which moves horizontally on a coordinate table (Fig. 1). Normally the DCS 300 takes about 30 minutes to cut a 10-carat diamond.

Now diamond processors have a faster and more flexible option for cutting large stones. Cool laser systems will slowly but surely replace mechanical saws.

Moscow – Cutting centre for stones from Siberia

Diamond cutting centres have sprung up in countries such as Botswana and Russia, which have their own large diamond mining operations and are keen to cut and polish high value diamonds.

Alrosa [6], the world's leading diamond producer in terms of number of carats mined, based in Russia, has a DCS 300 system (Fig. 5). Accounting for more than 28 % of global diamond production, the company produced 36.2 million carats of rough diamonds in 2014. Alrosa's major operations are in the Sakha region with 600 million carats of proven resources.

Alrosa has the advantage that its raw diamonds are sourced from its own mines. Diamond cutters in Belgium, China and India have to adapt their processes to differences in the stone structures of raw diamonds mined in different parts of the world such as Australia, Canada or Russia. In order to get optimal cutting performance, machine operators have to set laser parameters to ensure optimal performance for different stone structures.

Alrosa's DCS system can be easily optimised for cutting just Russian raw diamonds. Parameters such as laser frequency, pulse duration, laser power and water pressure can be tweaked to obtain the desired cutting results. The aim is to ensure a stable and reproducible process.

Future trends

"Up to now we have 34 DCS systems installed in countries as far apart as South Africa and Thailand," says Jörg Pausch, Head of Synova's Diamond Business Unit. "With our newly developed DCS 50, we will have a system where the optional 5-axis version will allow enhanced capabilities."

While Synova has made its mark in the diamond cutting sector, it has also supplied machines for slicing synthetic diamonds. Rough diamonds are a natural material and no two diamonds are alike. This is not the case with synthetic diamonds, which are manufactured in a laboratory.

Although synthetic diamonds have been manufactured by various processes for more than half a century, advances in recent years have made it possible to produce gem-quality synthetic diamonds of significant size. It is possible to make synthetic gemstones that, on a molecular level [7], are identical to natural stones and so visually similar that only an expert with special equipment can tell the difference.

Synthetic diamonds are also finding industrial applications in cutting tools, optics, semi-conductors and advanced sensor technology.

With its combined expertise in the diamond and industrial sectors, Synova is well positioned to supply systems for machining cutting tool inserts, laser mirrors and heat sinks for chips.

They say that diamonds are forever and Synova's future is linked with diamonds – whether they are natural or synthetic.

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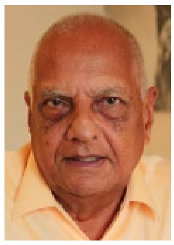
Fig. 5 Synova's Jörg Pausch (centre) with Alrosa executives in front of a DCS 300 system

Author



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