



SYNOVA CELEBRATES 25 YEARS OF DEVELOPMENT

Twenty-five years ago, Bernold Richerzhagen, Synova's founder, realized his vision of combining light and water to develop a hybrid method of laser machining superior to existing technologies.

The Genesis

Trade-marked as Laser MicroJet®, this technique combines a laser with a hair-thin water jet that guides the beam by means of total internal reflection. Since the water jet cools the cutting zone, hard and brittle materials can be machined without any thermal damage. This is a story of how the Laser MicroJet has been a game changer and revolutionized high-precision laser machining in the aviation, diamond and semi-conductor industries among others.

Synova's history begins when Bernold Richerzhagen, after obtaining his master's degree in mechanical engineering from RWTH University Aachen in 1989, applied for a position in a research project at the EPFL's Applied Optics Laboratory to develop a laser-based dental tool for the removal of caries.

Little did Richerzhagen realize that this project would result in an invention that would be a game changer in many industries. His invention was based on the fusion





Application development laboratory

of laser and water to drill tooth enamel. The laser beam was guided by total reflection within a fine water jet in the manner of an optical fibre. The laser provided the heat for ablation while the water cooled the material. This water jet guided laser offered the advantage of a parallel cylindrical laser beam, meaning without any beam divergence that is inherent in other laser processes.

After four years of extensive trials, Richerzhagen succeeded in coupling a high-power laser beam in a hair-thin water jet. Based on successfully proving the feasibility of a water jet guided laser for his dental tool project, Richerzhagen obtained his doctorate in 1994. The same year and, in the following years, he was awarded patents for his water jet guided laser beam process by the German and European patent offices.

Early Years

During 12 months of post-doctorate employment at the EPFL, Richerzhagen built a first functional model to find best operating parameters as well as convince potential industrial partners about his invention.

Afterwards, with the goal of commercializing his invention, Richerzhagen rented a facility at the EPFL's Scientific Park. From mid-1995 till mid-1997, he worked on developing his first prototype, named 'Machine 000'. By the time, he established Synova SA in 1997, the company received three awards for the new technology, later trademarked as Laser MicroJet (LMJ).

The first machine served as a laboratory tool for developing new applications as well as a machine for demonstration purposes in order to win customers. By now the 3-member team consisted primarily of engineers engaged in R&D and customer application testing. Although many customer samples were cut on the machine, there were very few orders. Looking back, it was logical because it was a new technology in a new product from a new company trying to enter in an old and traditional industry – the world of machine tools.

It was only in August 1999 that Synova shipped machine '001', a JPS 600, to American Dicing Inc., a job shop based in Liverpool, New York, USA. This resulted in the later introduction of the Laser Dicing System (LDS) for the electronics and semiconductor industry, which had the potential to revolutionize the way electronic chips were cut from wafers.

By 2001 the number of employees had grown to 15 and a new market opened up when Synova launched the LCS (Laser Cutting System) 300. The 3-axis LCS 300 (working



Slotted silicon disk



Synova's assembly hall

table size of 300 x 300 mm) was suited for a variety of precision machining applications. A milestone in the company's history took place when machine '012', the first LCS 300, was shipped in August 2001 to a job shop in Germany. The LCS 300 would become the company's workhorse. Most of the 13 LCS 300 systems shipped in 2002 were to customers in Germany, Japan, South Korea, Taiwan and USA.

In 2003, the company operation moved from the Scientific Park's incubation centre to a building located just across the EPFL campus. In psychological terms, the shift heralded a major change. In a symbolic way, the umbilical cord with the EPFL was cut off. Synova was now on its own.

Laser MicroJet for Semiconductors

Starting in 2003, Synova supplied several LGS (Laser edge-Grinding System) machines to Infineon Technologies AG, a European semi-conductor manufacturer. These systems are designed for the edge grinding of thin semi-conductor wafers.

In the same year, Synova launched the first Laser Stencil (LSS) systems. The first 3-axis LSS 800 systems, with a work table size of 800 x 600 mm, were shipped in 2004 to two customers in South Korea. One customer operated a stencil job shop. The other customer used the LSS 800 to cut OLED masks. These two applications highlighted the important role the LSS 800 (later LCS 800) would play in the semi-conductor industry. The LMJ technology, combining a laser with a water jet, was the ideal solution for machining silicon stencils without any heat affected zone.

In addition to the LGS system, Synova also developed the LDS system for wafer dicing and scribing applications. This dicing technology proved superior to the traditional blade dicing machines which sawed semi-conductor wafers into individual chips. LMJ technology allows

precise ablation of semi-conductor materials ranging from silicon, gallium arsenide to silicon carbide. The water jet guided laser guarantees a clean cut surface with no chipping, micro-cracks, burrs or depositions. There is no damage to the chips due to any heat-affected zone (HAZ). Finally, the process enables a high-throughput capability especially for thin wafers.

The pioneering LGS and LDS systems introduced laser cutting in the semi-conductor industry. In later years, Synova supplied such systems to semi-conductor manufacturers in Japan and Taiwan. Samsung Electronics of South Korea even integrated the LGS system into its production line for electronic chips by introducing robots for handling wafers.

One of Synova's biggest customer is a large semiconductor equipment manufacturer who uses LMJ technology for the cutting of silicon consumables used in etching machines. This customer has purchased 25 systems. Synova has been continually upgrading its LCS 800 systems to better serve the semiconductor industry.

Growth and Crisis

In recognition of his achievements, Richerzhagen was a finalist in Ernst & Young's 'Entrepreneur of the Year' award in 2004. Frost & Sullivan awarded Synova its prestigious European Award for Technology Innovation in 2005.

Although Synova was still a small enterprise with just 30 employees, Richerzhagen already had a global vision for the company. In the early years, the bulk of Synova's business came from the Far East and USA. In 2006, the company set up subsidiaries in Japan, South Korea and USA. He hired foreign nationals to manage these subsidiaries, which included micro-machining centers (MMCs) for customer application tests and job work. Synova was truly a multi-national company in every sense.

Aware of the threats from new technology disruptors, Synova entered into partnerships with various research institutes, including Fraunhofer ILT (Institute for Laser Technology) and Fraunhofer IPT (Institute for Production Technology), to adapt the LMJ process for new applications. The company also cooperated with industry players such as Carl Zeiss Jena on strategic projects to further optronics technology. In addition, it collaborated with University of Basle in the field of bio-medical engineering and University of Nottingham in advanced research on hybrid machining.

Meanwhile sales were also booming. The company shipped a record 26 systems in 2007. Most were for new applications for the patented LMJ technology ranging from the laser doping of photo-voltaic cells to cutting of stents and drilling of fuel nozzles.

In the same year, Synova launched the LMJ Integration Package (LMJ-iP) for sale to system integrators. This kit, comprising of core components (optical head, laser and water pump) enables users to integrate LMJ technology into their production systems. The first kits were sold to Schott Solar for integration in systems to cut solar wafers.

The 2008 financial crisis that hit the global economy also affected Synova's operations. Shipments were halved. Despite a cash flow crunch, the company managed to retain its around 60 employees, most employed either in R&D or application engineering. There was a slight recovery in 2009 when shipments increased.

Laser MicroJet for Cutting Diamonds

Fortunately, a new market opened up in 2010. After years of trials, Richerzhagen's team finally found the right laser parameters to cut diamond stones.

In 2011 Synova supplied its first LMJ DCS (Diamond Cutting System) 300 to Laurelton Diamonds Belgium BV, which is part of the Tiffany group. LMJ technology with its water jet reduced the risk of stones with air bubbles or inclusions getting damaged. In addition, Synova's 'wet' laser had many advantages over the widely used 'dry' lasers. In contrast to conventional lasers where the focused laser beam has a limited working distance of just a few millimetres, the water jet guided laser cuts with a cylindrical beam with a cutting depth that extends up to centimetres.

The DCS 300, a LCS 300 version adapted for cutting diamonds, became the machine of choice for cutting raw diamonds. A smaller version, the DCS 150, was added to the product offering. In the following years, shipments to the diamond industry added to the company's business volume.

Synova's LMJ technology has now become the industry standard for diamond cutting with more than 80 DCS systems in operation worldwide. In 2017 the 813-carat Constellation, the world's largest diamond with a length of 6 centimetres, was cut on a DCS 300 system.

With the diamond and cutting tool markets in mind, Richerzhagen decided to develop a compact machine with a smaller footprint and 5-axis capability. Not having the internal manpower resources to develop a mechanical platform, he sub-contracted the design work to an engineering college. The collaboration was successful, resulting in the LCS 50 – a machine with a work table of 50 x 50 mm.

Launched in 2014, the LCS 50 was an instant hit. The DCS 50, a machine version for the diamond market, became the optimal system for cutting diamond stones. Synova now had a versatile machine for the precision micro-machining of small components.



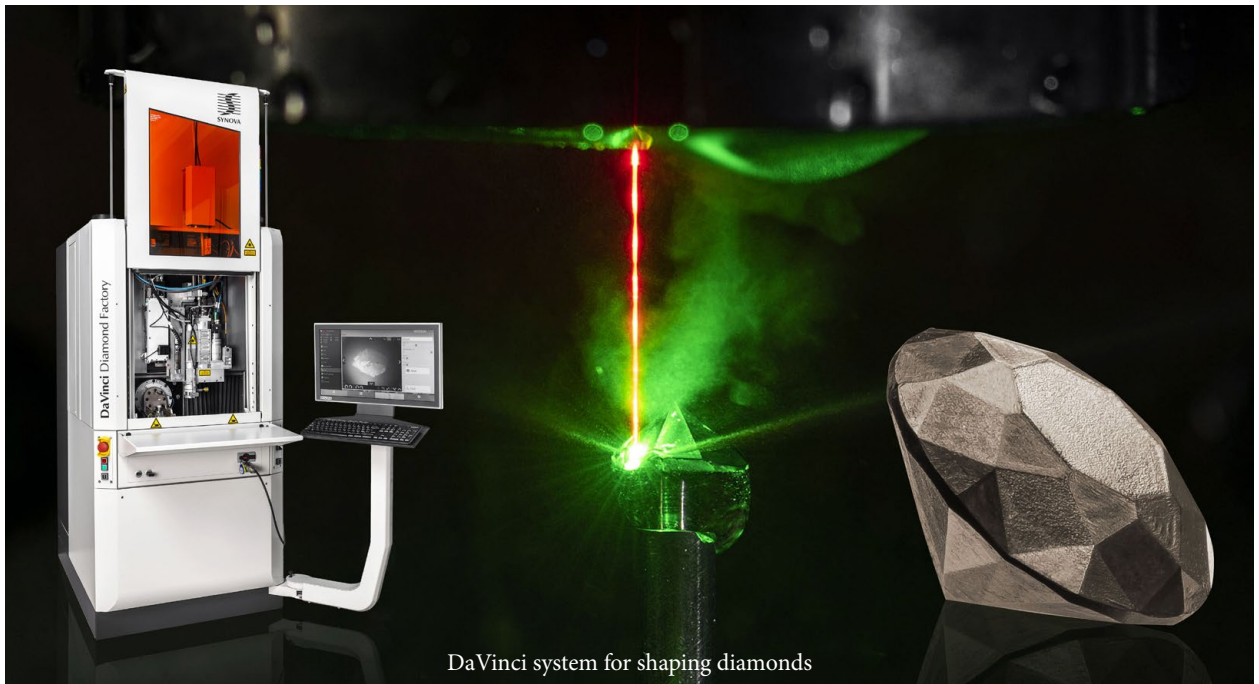
Final test of the DCS 50

Laser MicroJet for Jet Engine Parts

Meanwhile Synova had extended its business model to include technology licensing partnerships. In 2014 Synova partnered with Makino Milling Machine Co. Ltd. (Tokyo) to integrate LMJ technology into Makino's high precision mechanical platform. This partnership resulted in Makino integrating LMJ technology in two metal cutting systems: the 3-axis MCS 300 and the 5-axis MCS 500.

This partnership became a three-way collaboration between GE Aviation, Makino and Synova. GE had developed a ceramic matrix composite (CMC) to withstand high temperatures in jet engines. This extremely hard material was difficult to machine. Conventional machining and grinding on CMC shrouds took hours. By comparison, the LMJ-equipped MCS 500 drilled and cut the shrouds in few minutes without cracks and extremely low changes in the ceramic structure.

GE Aviation integrated the MCS 500 in its fully robotized production line to machine CMC turbine components. LMJ technology has changed the way how engine components will be machined in future.



DaVinci system for shaping diamonds

Laser MicroJet for Precision Machining

On 12 December 2016, Synova moved its international headquarters from Ecublens to larger premises in a modern building in Duillier. The availability of extra space was a boon for all key functions. R&D had its own space for prototype machines. Application Engineering got a larger bay in the production workshop. Production had space allocated for a second hall.

With the move to the new facility, the development of new machines took on a faster pace.

In September 2018, Synova launched the 5-axis LCS 305 for machining large components such as turbine blades and milling cutters. Incorporating state-of-the-art design components and technologies, the LCS 305 is the most accurate laser machine in its class. The machine is particularly suited for the machining of ceramic-matrix components used in aero-engines or milling cutter PCD inserts.

Synova shipped the first LCS 305 in 2017 to the Kennametal Group for their Technology Center in Latrobe, Pennsylvania (USA). A leader in the development of silicon nitride ceramic tools for the machining of exotic aerospace materials, Kennametal was following trends in cutting tool market. According to Dedalus Consulting, the market share of lab-grown diamond (LGD) tool bits had grown from 5% in 2004 to 17% in 2022. With its LMJ technology, the 5-axis LCS 305 is capable of machining the new generation of cutting tools made from polycrystalline (PCD) and monocrystalline (MCD) materials.

Sensing the need for a more versatile machine for high precision machining and for integrating all the sensors that Synova had developed over the past years, Synova

developed the LCS 303, replacing the successful LCS 300 that was built more than 150 times. Equipped with linear motor drives and a rotary axis for positioning the workpiece at different angles, this system was ideal for the slicing of CVD diamond cubes. Launched in 2020, the first system was shipped to Element 6, a De Beers subsidiary specializing in lab-grown diamond products.

In the meantime, Synova increased the licensing options for OEMs. The LMJ-iP package now includes options ranging from a reduced one with just a few components to a full-integration package with laser.

Synova also has OEM agreements with Makino in Japan, Arnold in Germany and C. B. Ferrari in Italy. After several years of successful partnership with Synova, Makino launched two LMJ-based systems in 2020 branded as Luminizer LB 300 and Luminizer LB 500 which Makino sells directly under its brand.

By 2019 the Synova group had around 100 employees and a product offering that ranged from the small 5-axis DCS 50 to the 5-axis XLS 1005 with the largest working volume. The timing was right for the next phase of product diversification.

Laser MicroJet for Diamond Shaping

In November 2020 Synova launched the DaVinci Diamond Factory®, a system that transforms rough diamonds into brilliant cut diamonds with up to 57 facets in a single operation.

The fully automatic DaVinci system is a technology

«The Rottweil location allows us to be closer to our customers in the German market, Austria and the Benelux countries.»

Bernold Richerzhagen, founder and CEO of Synova

disrupter. It promises to revolutionize the diamond industry as we know it by reducing throughput time from weeks to a few hours. Diamond manufacturers can achieve a higher polished yield out of their rough stones through greater accuracy, improved stone symmetry and reusable cut-off diamond chips.

The DaVinci machine polishes a 57-facet round brilliant in a different way. It first shapes the facets on the pavilion. This is where the laser beam can cut off large diamond chips that can be used for smaller gems. After shaping all the facets, the spindle rotates 90 degrees so that the laser beam can do the girdle bruting. Unlike in the manual procedure, this is the last operation.

Synova shipped the first machine in September 2021. Since then, more orders have been received. Diamond processors in Botswana and South Africa have placed orders for a DV-system since it replaces the need for skilled labour for the manual polishing of finished diamonds. Now it will be possible to mine a rough diamond and deliver the polished gem to the customer in a single day.

By the end of 2021, the group counted 120 employees with 400 LMJ systems sold worldwide.

Expansion and Future Vision

With a two-year order backlog, Synova was experiencing a production bottleneck.

Although construction of an 800 m² assembly hall is in completion in Duillier, there was a need to urgently build up additional production capacity. A plant in Rottweil (Baden-Württemberg) belonging to Mikron Germany GmbH was available for use. Synova took over this plant in June 2021, expanding its manufacturing capacity. In addition to assembling LMJ systems, this facility includes a micro-machining center (MMC) with showroom. “The Rottweil site allows us to move closer to customers in



the German market, Austria and the Benelux countries,” Richerzhagen stated.

Synova approaches its 25th anniversary in 2022 with 150 employees in the group. The company has set its vision for the future based on building energy efficient machines in an environment with a minimal carbon footprint.

The focus is on measuring and optimizing energy consumption at all levels. Future machines will be equipped with energy efficient drives. Machine architecture will be based on lightweight mobile structures. These changes will add up to big savings for customers.

With an aim towards reducing its carbon footprint, the company is moving towards clean energy. It has installed solar panels on its building tops to reduce peak power demand. The goal is to obtain at least two-thirds of the company’s annual energy needs from renewable sources.

The priority has always been customer satisfaction. It is now developing a system for the on-line monitoring of machine performance in the field to prevent machine failures. Such data, combined with AI, will enable the real time detection of extreme machine conditions and forecasting of critical spares such as laser diodes.

The first 25 years have witnessed a phenomenal development of the company. If the company continues its commitment to its core values of continual innovation and human resource development then there should be no cause for concern for the future.

Text : Nitin Shankar