

Volume 21 November / December 2024 / January 2025

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PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY

JPT

COVER STORY

Glass machining technology with
a ns-pulsed infrared fiber laser

**XIV JENAer
LASER
TAGUNG**

SPECIAL SECTION
XIV Jena Laser Conference

TECHNOLOGY REPORT

Raman spectroscopy and
imaging in bio and life sciences

PROCESS CONTROL

Optimized powder bed
laser melting processes

MACHINE VISION

3D vision helps to precisely
palletize parts

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Make it EPIC!

Driving Competitiveness of
European Photonics Industry
through an International Network

Next level – the Jena Laser Conference expands!

For many years, the Jena Laser Conference has been a must-attend event for experts in laser technology, especially for those with their focus on ultra-short-pulse lasers. This year, we are taking an exciting step by expanding the conference to a broader, more international audience. For the first time, the event will be held entirely in English, and we are delighted to welcome Lithuania as our special partner region for 2024.

What brings us together?

Jena and Lithuania have long been recognized as leaders in laser and photonics innovation. Both regions boast a strong tradition of excellence in research and development, particularly in cutting-edge laser technologies. Lithuania is known for its expertise in ultrafast lasers and optical solutions, while Jena continues to be a hub for pioneering advancements in photonics. By coming together, we seek to foster collaboration, share knowledge, and spark new ideas that will drive the future of laser technology forward.

What can you expect?

The Jena Laser Conference 2024 will spotlight significant advancements in laser technology and its diverse applications. Key topics will include ultra-short-pulse lasers, high-power laser systems, and innovative laser-based manufacturing processes such as welding, cutting, and additive manufacturing (3D printing). Another central theme will be the integration of lasers with sensors, enhancing precision and automation in industrial processes.

The conference will also cover the latest trends in micro-optics and beam shaping, with discussions on how these technologies are enabling new capabilities in various different industries. Innovative material processing technology will play a prominent role in the agenda too. The keynote speakers, who are leaders in the global laser industry and research, will offer invaluable insights into the future of these technologies and their potential to reshape industries worldwide.

We look forward to welcoming many participants to Jena for what promises to be an inspiring and forward-looking event! Be invited to explore the conference articles on selected topics in PhotonicsViews.



Anke Siegmeier

Nora Kirsten

Managing Directors,
OptoNet e.V. – the central German Photonics Cluster

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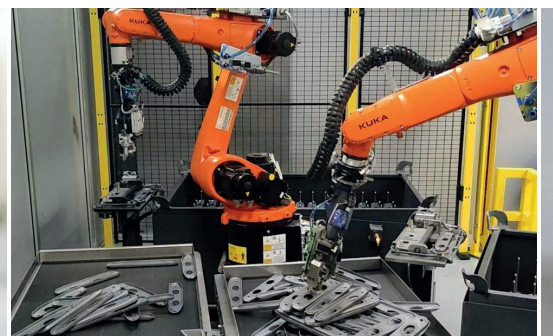
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Jena Laser Conference

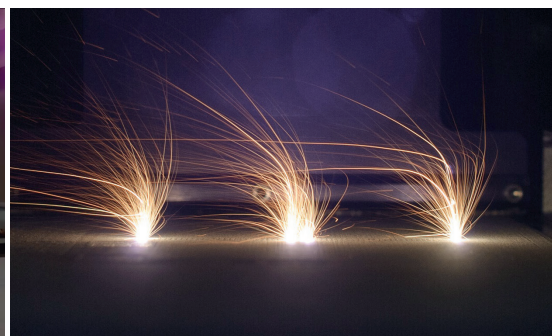
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Combining freeform optics and deformable technology for minimized line widths

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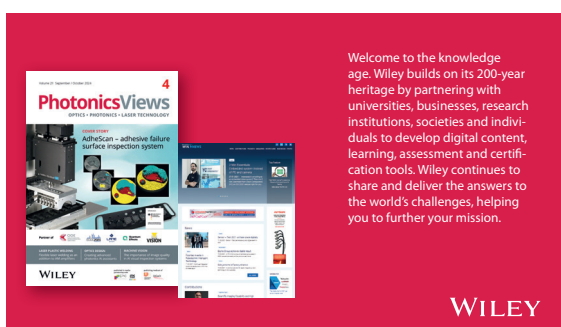
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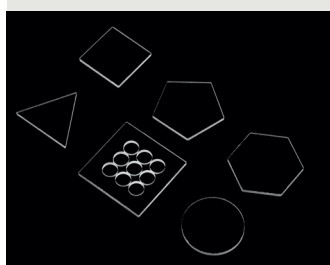
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Stable processes are a challenge – machine vision provides insights and enables better control



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Cover:

With the development of high peak power nanosecond-pulse infrared lasers, glass processing has improved significantly. Such lasers provide advantages in manufacturing irregularly shaped glass.

p. 28

New report: photonics key to limitless clean energy

A new analysis published by Photonics21 highlights the critical role photonics plays in developing fusion power. Called 'Photonics for the Energy Production Market: Focus on Fusion Energy,' the report reveals that light technologies are vital for

nucleus and requires temperatures of around 100 million degrees Celsius with immense pressures to overcome the repulsive forces between the positively charged nuclei.

This latest research, conducted by French market

high-precision components required for fusion reactors.

According to the report, powerful lasers, which are essential for initiating fusion reactions in inertial confinement fusion, are used to mimic the conditions inside stars by compressing and heating fuel pellets. The report shows that photonics is also a viable option for controlling fusion plasmas with great precision and managing the extreme temperatures involved in fusion reactions.

Photonics21 president Dr Lutz Aschke said: "We see that lasers and optical technologies have the potential to turn the science fiction dream of limitless fusion power into a reality. We are already optimizing and expanding renewable energy sources using photonics today, such as advanced thermographic cameras that detect faults in electrical systems, lidar technologies that enhance wind turbine efficiency and lasers for improved photovoltaic cells. This cutting-edge science and technology has the

power to make what once seemed impossible – clean, sustainable power for all – into a tangible goal."

According to the study, photonic technologies like lidar, optical sensors, and high-precision imaging, will be crucial for monitoring and controlling the extreme conditions within fusion power plants, which will ensure the stability and efficiency of the fusion process.

The report discusses a number of fusion approaches, where photonics is essential for manufacturing complex components and the high-precision assembly for these reactors, including magnetic confinement in tokamaks and stellarators.

The report reveals that no matter what the fusion approach, and even when the confinement is magnetic or electrostatic, no fusion reactors can work without photonics as a critical enabler.

www.photonics21.org
<https://tematys.fr>



Magnetic confinement fusion main concepts: Tokamak (pictured: JET) and Stellarator

advancing future clean energy sources and are key to enabling critical processes necessary for fusion power.

Fusion power involves combining two light atomic nuclei to form a heavier

intelligence group Tematys, shows that while fusion energy is an extremely complex endeavor, photonics – or the science of generating and harnessing light – is essential for developing the

Manufacturing: good prospects for 2025

The global manufacturing economy was sluggish in 2024 and is forecast to expand by just 0.6 % compared with last year. However, it looks set to recover in 2025, according to data released by Interact Analysis in summer. The market intelligence expert explained, except for China, most territories will experience a slight contraction this year, but many will be better off than expected going into 2025.

Although Interact Analysis has lowered growth forecasts for 2025 in its latest manufacturing industry output (MIO) tracker, this is the result of a slightly improved global outlook for the end of

2024, which will in turn see most economies finish the year in a stronger position. A slight dip in the growth rate is anticipated in 2026, but manufacturing output is expected to maintain a relatively steady positive trajectory out to 2028.

It is still unclear where the global manufacturing recovery will come from, and until there is an upturn it is difficult to judge the potential strength. Despite optimistic signs for other territories, the latest MIO includes a slight downward revision for China compared with the previous edition; from 2.8 to 2.4 %. China as 'the factory of the world' is responsible

for almost half of the total manufacturing market value and any further reductions in the country's forecast could well lead to a small contraction in the global MIO figure for 2024.

Consumer resilience coupled with inflation and interest rates slowly starting to fall is pushing up spending worldwide and the US manufacturing economy is strengthening. The semiconductor industry has bounced back from a low point in 2023, boosting outlook for parts of South-Asia heavily reliant on the market sector, including Taiwan, Singapore and South Korea. Dwindling order books and the impact of the higher cost of living

have constrained global demand, but there are signs of recovery in consumer spending and post-Covid supply chain problems have eased considerably.

However, there are various economic indicators pointing to a more challenging environment for manufacturers. All four major European manufacturing economies are in a downward cycle, and sentiment for the year remains gloomy. Positive signals from the US may well start to manifest in other regions later in the year, but this has yet to be seen.

<https://interactanalysis.com>

Lynred acquires NIT

Lynred, a global provider of high-quality infrared sensors for the aerospace, defense and commercial markets, takes over shortwave-infrared imaging modules and sensors provider New Imaging Technologies (NIT). In a strategic move to consolidate its leadership in infrared sensors, Lynred's product portfolio will expand to include high-definition large array SWIR sensors in small pixel pitch, bolstering its product offering across all wavelength bands (short to very longwave). The transaction is expected to close in Q4, 2024 and is subject to customary conditions.

The deal includes NIT's large and innovative port-

folio of SWIR products (imaging sensors and modules) and a portfolio of wide dynamic range patents. This enables Lynred to offer global customers large format SWIR sensors with advanced capabilities for applications in markets where AI, deep learning and multispectral imaging are driving growth.

NIT, a vertically integrated company with two dozen employees, is the only European firm to manufacture and market a SWIR HD1080p array and associated module at a pixel size of 8 μm , a key asset for several applications that Lynred will now leverage.

www.lynred.com
new-imaging-technologies.com

AMS Osram opens new design center in Valencia

Its new building marks a significant milestone in the trajectory of the company to lead innovation in medical imaging technology on a global scale. Although AMS Osram has been operating in Valencia for 16 years, this new center, located in the iconic building at 60th Colon Street, reaffirms the company's commitment to

has become a hub of innovation in medical imaging technology. The CT and X-ray sensors developed ensure highest reliability and outstanding performance, making medical diagnostics more accurate and enhancing diagnostic value with sharper images while reducing radiation doses for improved patient care.



The new center, located at 60th Colon Street

innovation, development, and university collaboration, while positioning itself as a leading employer for design engineers in the region.

The company's design center in Valencia has been a fundamental pillar in the development of technologies that allow medical imaging OEMs to produce high-precision images with minimal radiation doses. Since 2010, shortly after its inception, it

In recent years, AMS Osram has established itself as a pioneer in the field of medical and industrial imaging, offering advanced solutions for CT and digital X-ray. With this new design center, the company plans to develop next-generation solutions that improve the quality of medical diagnostics and, ultimately, patient care.

<https://ams-osram.com>

EOS cooperates with nLight



Marie Langer (CEO EOS, right) and Scott Keeney (CEO nLight)

The American provider of high-power semiconductor and fiber lasers and the German experts for additive manufacturing (AM) technologies, pursue a joint strategic technology cooperation, making nLight's beam shaping lasers available in EOS' metal AM systems.

The cooperation includes the implementation of a series of complementary laser-based technologies to optimize the AM light engine for robust indus-

trial 3D printing production. The companies plan to make beam shaping and light engine optimization capabilities available digitally, enabling customers to access different beam profiles via EOS software to activate higher productivity printing. AMCM, an EOS Group company focused on customized AM solutions, has already made the program-mable AFX laser available in its metal AM systems.

www.nlight.net ■ www.eos.info

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PI: new building to support sustainable strategy with goal of tripling capacity



(l-r) Markus Spanner and Dr Axel Widenhorn (PI) receive a symbolic key from Rudolf Harsch and Markus Oechsle (Harsch Bau)

On September 16, 2024, Physik Instrumente (PI) inaugurated the new building of its Eschbach site in the Breisgau Business Park in southwestern Germany. Investments of approximately 20 million euros support the expansion of the global development and production center and strengthen the economic development of the region with state-of-the-art jobs.

In addition to the new building in Eschbach, other important milestones in PI's investment strategy include investments in other sites in Germany, the USA, China, and Japan.

The company plans to triple the site's capacity; the new building provides an additional 6,500 square meters of space. It was designed to meet the highest environmental standards. In addition to the use of sustainable building and insulation materials, a 213 kW_p photovoltaic system was installed on the roof, generating renewable electricity, and contributing to the energy transition.

In addition to the new building, the district heating concept has also been applied to the existing plant.

www.physikinstrumente.com

Laserline takes over WBC Photonics

By securing a seventy-percent stake in the Boston-based laser specialist, Laserline is expanding its solution portfolio to include blue industrial diode lasers with particularly high beam qualities of better than 4 mm mrad. This positions Laserline as a full-service provider for diode lasers in the blue wavelength range and covers a broad product spectrum from systems with high focusability to power levels in the multi-kW range.

WBC Photonics was founded through a management buyout of the former Panasonic subsidiary TeraDiode and produces high-power diode lasers in the NIR and blue wavelength

spectrum. The high beam quality of the laser systems is achieved through emitter-based wavelength beam combining. The acquisition opens up new target markets for Laserline. The high focusability is important for applications in the field of additive manufacturing, welding, or cutting for example.

"Our new partnership with Laserline enables access to markets worldwide for high brightness blue lasers," said WBC Photonics CEO Michael Deutsch. "Together, we will become the world leader in blue diode laser technology."

www.laserline.com
<https://wbcphotonics.com>

EssilorLuxottica acquires majority stake in Heidelberg Engineering

Drawing on EssilorLuxottica's long-standing expertise in the design and manufacture of advanced instruments and vision care solutions for eyecare professionals, the agreement for the acquisition of an 80 % stake in the Germany-based company specializing in diagnostic solutions, digital surgical technologies and healthcare IT for clinical ophthalmology Heidelberg Engineering represents a step forward in the group's strategy and its med-tech journey.

Founded by Dr Gerhard Zinser and Christoph Schoess in 1990, Heidelberg Engineering brings extensive technological and scientific expertise in optical coherence tomography (OCT), real-time image processing and analytics, large-scale data analysis, and digital surgical navigation,

to serve medical professionals, scientists and researchers across a broad range of ophthalmic areas.

With a presence in more than a hundred countries, Heidelberg Engineering has been a reference in early detection of sight-threatening conditions such as glaucoma and age-related macular degeneration. As part of EssilorLuxottica, Heidelberg Engineering will continue to serve the market under their well-established brand, delivering the same solutions and expertise their customers have come to expect and trust.

The transaction is expected to close in H2 2024 pending regulatory approvals and other customary closing conditions.

www.essilorluxottica.com
www.heidelbergengineering.com

Optosurf becomes part of the Mahr group

The takeover that was announced in July enables Mahr to expand its optical surface metrology portfolio and enhance the assessment of tribological properties. The acquisition will allow Mahr to offer more advanced options to its customers, improving the ability to measure surfaces extremely accurately and efficiently while supporting the minimization of friction, reduction of wear, and improvement of system efficiency.

The scattered light technology initially developed by Optosurf presents significant advantages, especially for finely machined surfaces with high functional requirements. It can detect roughness down to the nanometer range, deriving surface parameters from the distribution of micro-profile angles within the measuring spots rather than from a height profile as with con-

ventional tactile or optical methods.

The rougher the surface, the greater the angle distribution and the wider the scattering of the reflected light. This angular information is closely related to the friction behavior of surfaces in tribological systems.

The technology's high vibration and distance insensitivity make it suitable for direct use in the production environment, and its high-speed measurement capability allows for the evaluation of up to 100 % of surfaces. Due to the high accuracy of the sensor system, this technology is ideal for finely machined surfaces with high functional requirements, especially for applications in electromobility, mechanical engineering, aerospace technology, medical technology, and semiconductor technology.

www.mahr.com
www.optosurf.de

ECOC Exhibition Industry Awards presented in Frankfurt

The organizers introduced the ECOC Exhibition Industry Awards in 2020 to celebrate the 25th anniversary of the exhibition. The winners were announced live at the event – this year in Frankfurt, Germany – in the Product Focus theater on Tuesday, 24 September, with some winners repeating the success from last year's event in Glasgow, Scotland.

After winning the trophy in the innovative photonics component category last year, Coherent has won the 2024 ECOC Exhibition Industry Award for best product in the data cen-

ter innovation category for its Datacenter Lightwave Cross-Connect (DLX) optical circuit switch.

Also on the podium again were China Mobile, this time for the most innovative PON / 5G / FTTx product, Huawei who won the optical transport award, Lightwave Logic repeating their success in hybrid PIC / optical integration platforms, and Marvell, this year in the most innovative pluggable transceiver / co-packaged module category.

Also on stage were Nano-scribe for the most innovative chip-scale packaging /



Source: ECOC

Group picture after the award ceremony

optical sub assembly, New-Photonics in the most innovative photonics component category, Source Photonics who took the post-deadline award for their Compact 50G PON OLT/ONU SFP56

and SFP-DD product family, Sumitomo Electric Europe winning the best fiber / fiber component prize, and Yokogawa for the most innovative test equipment.

www.ecocexhibition.com

Quantum Effects Awards presented in four categories at the Stuttgart trade fair

As part of the Quantum Effects trade fair opening ceremony, representatives of four companies from Germany and abroad received the winners' trophies for their new developments in four areas.

In the Quantum Computing Hardware category, the award went to Quantinuum from Broomfield, Colorado. They have developed a system that has more Qubits than can be precisely modulated with supercomputers – with a 30,000-fold energy saving compared to the supercomputer.

The Saarbrücken-based company Qruise received an award in the Software & Algorithms category: with

the help of artificial intelligence, they created a software solution that enables the systematic planning and execution of experiments with quantum computers.

The winner in the quantum sensor technology category was SBQuantum from Sherbrooke in the Canadian province of Quebec. The team has succeeded in developing a sensor that enables extremely precise navigation in aviation and can even be used in space due to its robustness. The company's sensor technology has already been tested in several field trials in Canada.

Finally, Attocube Systems from Haar in Upper Bavaria received the award in the



Happy winners, laudators and presenters on the Green Stage at Quantum Effects (Source: Landesmesse Stuttgart)

Quantum Communication & Networks category – for a transportable, space-saving cooling cube which, according to the jury, revolutionizes the cooling of quantum systems and thus makes a

very important contribution to the use of quantum systems.

www.messe-stuttgart.de/quantum-effects

Werner von Siemens Ring goes to Zeiss and Trumpf

The 42nd 'Werner von Siemens Ring' will be awarded to the EUV development teams of Zeiss and Trumpf. The Werner von Siemens Ring Foundation is thereby honoring researchers from both companies for the development of High-NA-EUV lithography and the industrial utilization of EUV technology. Dr Peter Kuerz (Zeiss SMT) and Dr Michael

Koesters (Trumpf) will receive the award on behalf of their entire teams on December 13 in Berlin. The 'Werner von Siemens Ring' is considered one of the highest German honors for individuals who have significantly advanced technical sciences through their achievements or have opened up new paths as researchers.

The award winners have made a significant contribution to the development of this future technology with the development of High-NA-EUV lithography and the industrial utilization of EUV lithography. Thanks to this technological leap, even more powerful microchips can be produced starting from 2025. This is made possible by the world's most

powerful pulsed industrial laser for exposing state-of-the-art microchips from Trumpf and Zeiss' optical system, which incorporates the most precise mirrors in the world. Together, they are used in lithography machines of the strategic partner ASML.

<https://siemens-ring.de>

The winners of the Inspect Award 2024 were honored at the Vision trade fair



Together with the readers of the Inspect magazine, the jury of the Inspect Award has selected three winners in two categories. The jury included Paul-Gerald Dittrich (Spectronet), Dr Ronald Müller (Vision Markets), Anne Wendel (VDMA), Thomas Lübckemeier (EMVA), and Prof Dr Michael Heizmann (Karlsruhe Institute of Technology).

In the 'Vision' category, the Baumer group was in first place for their VCA industrial cameras. Autovision came in second with their hygienic protection and mounting kit for camera systems. Third was Edmund Optics with the fixed focal length lenses of the UAV series.

In the 'Automation & Control' category, Hama-

matsu Photonics Germany won the first prize for the UV microspectrometer C16767MA. Wenglor Sensoric was second with the laser distance sensors of the P3 series. The last trophy went to Balluff for the Radarimager 3D imaging system.

www.wileyindustrynews.com

Jürgen Czarske receives Dennis Gabor Award at San Diego conference

The SPIE Dennis Gabor Award in Diffractive Optics 2024 was presented to the TU Dresden professor Jürgen Czarske in August during SPIE Optics + Photonics. It is named for the Hungarian-British electrical engineer and physicist who is most notable for inventing holography, for which he later received the 1971 Nobel Prize in Physics.

Czarske, a professor of computer and electrical engineering, is a widely recognized inventor of laser technologies and diffractive optics innovations in imaging, information technology, and holography. His outstanding accomplishments in diffractive wavefront technologies have advanced the development of digital

holography and metrology applications such as green photonics, biomedicine, and multimode fiber communications. In one of his most well-known achievements, he introduced a truly game-changing paradigm shift in laser Doppler velocimetry (LDV) metrology by overcoming the diffraction-induced complementarity of distance and velocity measurements. This groundbreaking success led to real-world applications from plasma technology and noise-reduction in aircraft engines, to green photonics-related energy-efficient processes in fuel cell stacks.

The society has previously recognized Czarske, an SPIE Fellow, with its 2022 Chandra S. Vikram Award in Optical



Jürgen Czarske accepts the award from SPIE president Jennifer Barton (Source: SPIE)

Metrology. The advisor of the SPIE Student Chapter at TU Dresden and elected vice president of the International Commission for Optics, Czarske is also an active member of multiple conference program committees at SPIE Photonics Europe.

"It is a special honor to receive an award with the

name of a Nobel Prize winner and to be included on the list of our own heroes as a prize winner, a privilege for the entire team and the cooperation partners to whom the Gabor Award is dedicated," Prof Czarske commented.

<https://spie.org>

Andrés Lasagni elected to WLT

Prof Dr Andrés Fabián Lasagni has been elected as a member of Wissenschaftliche Gesellschaft für Lasertechnik (WLT). The admission to the scientific society honors contributions to laser-based manufacturing



Andrés Fabián Lasagni (Source: Fh. IWS)

and innovation. The election occurred during the society's recent general meeting, recognizing his pioneering work in laser-based manufacturing and his role in advancing sustainable technologies. Lasagni is the chair of laser-based manufacturing at the Institute for Manufacturing Science and Engineering at Dresden University of Technology and the director of the Center for Advanced Micro-Photonics (CAMP) at Fraunhofer IWS.

Lasagni, of Argentinean, Italian, and German descent,

received an MSc in chemical engineering from National Comahue University, Argentina, in 2002 and a PhD in materials science from Saarland University, Germany, in 2006. From 2007 to 2008, he was a research scientist and Alexander von Humboldt Fellow at the Georgia Institute of Technology. From 2008 to 2017, he was a group leader at the Fraunhofer Institute for Material and Beam Technology IWS, developing several optical concepts for direct laser interference pattern-

ing (DLIP). Since 2012, he has been a professor at the Institute of Manufacturing Technology at the Technische Universität Dresden, and since 2017, he has been the director of CAMP in cooperation with Fraunhofer IWS.

His research focuses on developing functionalized surfaces using laser-based methods, creating optical devices for high-throughput laser texturing, and innovating in-line monitoring systems.

www.wlt.de

Change of CEO at Zeiss in 2025



Andreas Pecher (l), Dr Karl Lamprecht

After almost twenty years at Zeiss, Dr Karl Lamprecht has decided not to extend his contract as president and CEO. The supervisory board has appointed Andreas Pecher as the new president and CEO effective 1 April 2025. Pecher joined Zeiss in 2013, and he has been a member of the executive board, responsible for the Semiconductor Manufacturing Technology (SMT) segment, since 2022.

The supervisory board opted for continuity also in the new appointment of executive board members and contract extensions, so Dr Frank Rohmund was

appointed a member of the executive board and head of the SMT segment effective 1 January 2025, where he currently heads the Semiconductor Manufacturing Optics (SMO) strategic business unit.

In addition, the supervisory board extended the contracts of Susan-Stefanie Breitkopf and Sven Hermann by five years until 2030. Both were appointed members of the executive board in 2022 – Breitkopf as chief transformation officer and Sven Hermann for the consumer markets segment.

www.zeiss.de

Jenoptik extends contract with Stefan Traeger



Dr Stefan Traeger

The supervisory board of Jenoptik AG has reappointed Dr Stefan Traeger as chairman of the executive board for a further three years. With effect from July 1, 2025, the new term runs until June 30, 2028. "Under the leadership of Dr Traeger, Jenoptik has been very successful in recent years in developing into a profitably growing, focused photonics group. Continuity in the management of the company by Dr Traeger creates the basis

for realizing the organic growth potential and thus consistently implementing our strategy," said Matthias Wierlacher, chairman of the Jenoptik supervisory board.

"I look forward to continuing to work with my colleagues on the executive board, employees, customers and shareholders and thank the supervisory board for the trust they have placed in me," said Traeger. "I would like to continue the successful path we have embarked on together."

Together with the other members of the executive board, Dr Traeger has been shaping the strategic realignment and focus of the company since 2017.

www.jenoptik.de

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www.scanlab.de

ALSO OF INTEREST

3D-Micromac systems for Infineon

Laser micromachining expert exclusively supplies new Dresden Smart Power Fab with the microVEGA FC laser trimming system

LPKF builds network to innovate glass substrate production

Company joins forces with partners to build glass-focused supply chain for advanced semiconductor packaging

Union Park Capital has bought IIM

The company will become a subsidiary of group member Exaktera beside Z-Laser, ProPhotonix, and Advanced Illumination

SuperLight Photonics expands reach with strategic partnership in Japan

Spin-off company from the University of Twente is expanding its footprint in the Asia-Pacific region

Senswork expands premises

Innovation Lab in Munich is expanding to 150 square meters, twice the area than before

Balluff establishes new business division

The company is expanding its range of camera and sensor technology with Custom Design & Engineering (CDE)

AT presents new branding and logo

"AT – Automation Technology" becomes "AT Sensors"

German-British collaboration in high-performance photonics

Berlin-based Ferdinand-Braun-Institut and the University of Glasgow deepen their cooperation, focusing on ultrahigh-power photonic applications

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**Toptica Photonics expands executive board**

The company has added two distinguished professionals and long-standing employees to its executive board. While Dr Mathias Schindler has taken on the role of chief operating officer (COO), Fabian Uhl has been appointed as chief financial officer (CFO). The company is continuing its growth path based on Toptica's products and market experience in quantum technology, biotechnology, and test and measurement.

Dr Mathias Schindler brings extensive experience to his role as COO, where he will manage production,



Source: Toptica

Dr Mathias Schindler

purchasing, logistics, information technology, real estate, and quality assurance.

Fabian Uhl will be responsible for the group's finances, including accounting, financial planning and control, and corporate con-



Source: Toptica

Fabian Uhl

tract review. Additionally, he will serve as the primary contact for banks and auditors. "Create transparent and comprehensible finances as a basis for good decisions," Uhl says.

www.toptica.com

iPrionics appoints Christian Dupont as CEO

The provider of reconfigurable photonics, iPrionics, has introduced Christian Dupont as its new chief executive officer. He comes with more than thirty years of experience in high-tech business and strategy development. His appointment comes at a crucial time as the company prepares to launch its first optical switch for AI clusters and datacenter applications. This product is based on software-defined integrated photonics and will enable flexible optical

networking while reducing system cost, power consumption, and latency.

"We are thrilled to welcome Christian to the iPrionics family," said Dr Daniel Pérez López, CTO and cofounder. "His expertise in both business development and scaling up deep tech companies makes him the ideal leader to guide iPrionics through its next phase of growth and innovation."

Prior to joining iPrionics, Dupont served as Texas Instruments wireless general



Source: iPrionics

Christian Dupont

manager in USA and Europe and was CEO of several optical MEMS startups. He holds a master of engineering from the Ecole Polytechnique Fédérale de Lausanne.

<https://iprionics.com>

Schuler under new management

Martin Drasch, became CEO as of October 1, 2024. "We are very pleased to be able to fill this important position within the Andritz group," says president and CEO Dr Joachim Schönbeck. "The market situation in the automotive and supplier industry is currently quite challenging. We are therefore fortunate to have found a successor in Martin Drasch, who has extensive knowledge and experience in the automotive industry as well as in-depth industry expertise in the future topics of electromobility and bat-

tery production. I am convinced that he will set the right course for Schuler."

"Schuler is a top innovative company with great potential in the field of battery production. I am therefore looking forward to this new task," says Drasch. The 49-year-old has been CEO of Manz, which employs around 1,400 people, since 2018.

Drasch built up the mobility and battery solutions division there and initiated a cooperation with the Dürr and Grob companies on the topic of 'turn-



Source: Schuler

Martin Drasch

key battery factory'. The mechanical engineering graduate previously worked as chief operating officer (COO) at Manz and in various management positions at Eisenmann.

www.schulergroup.com

Ultrathin optical filters from Everix

Distributor: AHF analysentechnik

Product: The new, innovative polymer filters from the manufacturer Everix are ultrathin (0.1 – 0.5 mm) and can be installed particularly well in devices or systems where conventional glass filters reach their limits.

Features: The Everix polymer filters can be attached to curved surfaces and cut to special shapes. This is made possible by an innovative, patented thermal manufacturing process that opens up a great deal of scope in terms of the shape and application of the filters. In addition to customer-specific designs, the following standard versions are available: single and mult notch filters (OD6+), bandpass filters (FWHM >25 nm, OD2 – 4), narrow bandpass filters (FWHM <10 nm, OD2 – 6), long-pass and short-pass filters (OD2 – 4).

Everix's manufacturing process is based on the thermal stretching of a multilayer block (as a preform) into a substrate-free, ultrathin optical filter. This process is sim-



ilar to the way optical fibers are thermally drawn from a fiber preform and is even more economically scalable than previous coating-based methods of manufacturing optical filters.

Applications: AHF will be of assistance in developing the right ultrathin filter design for any particular OEM project, e.g. in the life sciences and medical technology, in sensors for industry, robotics, the Internet of Things, or in consumer electronics. Through the company's direct contact

with the manufacturer, it can quickly clarify the feasibility and accompany the realization of the design.

AHF analysentechnik AG

Kohlplattenweg 18
72074 Tübingen
Germany
phone: +49 7071 5395 200
fax: +49 7071 5395 299
e-mail: info@ahf.de
Web: www.ahf.de

Photoreceiver / optical power meter for femtowatt to milliwatt

Manufacturer: Femto Messtechnik

Product: Ultralow-noise photoreceiver series OE-200 with variable gain from 10^3 to 10^{11} V/W. Compact and user-friendly design for easy integration into optical measurement systems. Fiber optic and free space input available. The product line covers optical wavelengths from 190 nm to 1700 nm and includes models with calibration at 850, 1310 or 1550 nm.

Features: An outstanding characteristic of the OE-200 series is the combination of high speed, ultralow noise and wide gain range. The high bandwidth of up to 500 kHz allows measurement speeds of up to one million readings per second and thus supports the precise measurement of dynamic and modulated signals. The ± 10 V output signal can be easily read using standard voltmeters, oscilloscopes or AD converters, which can also be used to set up a fast and highly sen-

sitive optical power meter. The sophisticated circuit design with an input noise (NEP) down to 6 fW/√Hz enables the low-



noise measurement of optical signals from femtowatt to milliwatt range. Due to its robust, compact and high-quality

design, the OE-200 can also work without problems in environments with strong electromagnetic interference. It is easy to operate and can be controlled either completely manually or via a digital interface (USB optional).

Applications: The OE-200 is suitable for a wide range of applications, like spectroscopy, characterization of light sources, fast optical power monitoring, time-resolved pulse measurements and many more.

FEMTO Messtechnik GmbH

Klosterstr. 64
10179 Berlin
Germany
phone: +49 30 28047 110
fax: +49 30 28047 1111
e-mail: info@femto.de
Web: www.femto.de

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An inkjet-printed microlens array for compact cameras

Palm-sized multispectral 3D camera could improve autonomous driving and remote sensing



A multispectral version of a light field camera

Researchers have used inkjet printing to create a compact multispectral version of a light field camera. The camera, which fits in the palm of the hand, could be useful for many applications, such as autonomous driving, classification of recycled materials and remote sensing. 3D spectral information can be useful for classifying objects and materials; however, capturing 3D spatial and spectral information from a scene typically requires multiple devices or time-intensive scanning processes. The new light field camera solves this challenge by simultaneously acquiring 3D information and spectral data in a single snapshot.

“To our knowledge, this is the most advanced and integrated version of a multispectral light field camera,” said

Uli Lemmer from the Karlsruhe Institute of Technology in Germany. “We combined it with new AI methods of reconstructing the depth and spectral properties of the scene to create an advanced sensor system that acquires 3D information.” The new camera and image reconstruction methods can be used to distinguish objects in a scene based on their spectral characteristics. Using inkjet printing to make the camera’s key optical components allows it to be easily customized or manufactured in large volumes.

“Reconstructed 3D data from camera images are finding widespread use in virtual and augmented reality, autonomous cars, robotics, smart home devices, remote sensing and other applications,” said Michael Heizmann, a member of the research team. “This new technology could, for example, allow robots to better interact with humans or improve the accuracy of classifying and separating materials in recycling. It could also be potentially used to classify healthy and diseased tissues.”

To create a multispectral light field camera, the researchers used inkjet printing to deposit a single droplet of material to form each individual lens on one side of ultrathin microscope slides and then printed fully aligned color filter arrays on the opposite side

of the microscope slides. The resulting optical component was integrated directly onto a CMOS camera chip. The inkjet printing method allowed precise alignment between the optical components, significantly reducing the manufacturing complexity and enhancing efficiency. Because this setup produces spectral and depth information that are interwoven in the camera image, the researchers developed methods to separate each component. They found that an approach based on deep learning worked best for extracting the desired information directly from the acquired measurements.

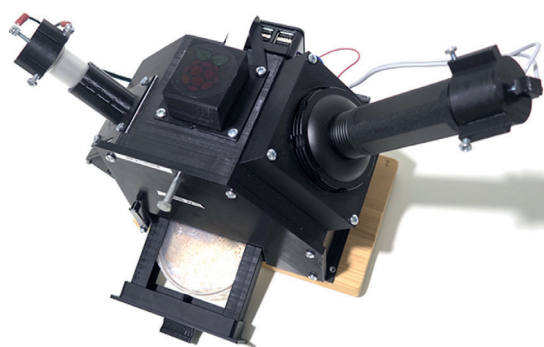
“Tackling the challenge of creating a multispectral light field camera was only possible by combining recent advances from manufacturing, system design and AI-based image reconstruction,” said Qiaoshuang Zhang. “This work pushes the boundaries of inkjet printing – a versatile method with high precision and industrial scalability – for manufacturing photonic components.” (Source: Optica)

Q. Zhang et al.: Compact multispectral light field camera based on an inkjet-printed microlens array and color filter array, *Opt. Exp.* 32, 23510 (2024); DOI: 10.1364/oe.521646

www.lti.kit.edu

3D-printed imaging device for education and microbial research

A low-cost imaging system for near-infrared fluorescence detection of phototrophic cell colonies



The NIRis 3D-printed device enables students and researchers to observe and study natural phenomena (Source: O. Franz, U Jyväskylä)

Researchers at the University of Jyväskylä have developed an imaging device for schools and research centers to study microbes. The NIRis 3D-printed device enables schools to observe and study natural phenomena. Researchers will gain useful and new knowledge about the light-activated bacteria. The Shared Light project at the University of Jyväskylä aims to understand the role of photosynthetic bacteria inside plants, and utilizes citizen science.

“Seven different high schools across Finland, from Utsjoki to Turku,

collected hundreds of plant samples for the researchers who then isolated bacteria from the plants,” said project researcher Ole Franz from the University of Jyväskylä. In order to facilitate fast detection of the bacteriochlorophyll-containing bacterial colonies of interest, the researchers developed a low-cost imaging device, the ‘Near-infrared imaging system’ (NIRis) to analyze bacteria. NIRis has two imaging modes, resulting in an overlay of all bacteria colonies and selectively identified near-infrared fluorescent colonies. The identified bacteria

can then be easily isolated for further studies. The 3D-printed device houses regular flashlights and detects bacterial colonies using a small Raspberry Pi computer and camera module.

The aim was to keep the costs low and make it easy to operate. The low costs – less than thousand euros – and easy operation allowed production of multiple devices so they could be sent to high-schools participating in the project, says Heikki Häkkänen, the main designer of NIRis from the University of Jyväskylä. NIRis makes it possible to realize new types of multidisciplinary research and teaching at schools and research institutes. Teachers could utilize the device for example in biology, physics, programming, material design or even art education.

“This is a great opportunity for teachers to link regular courses to relevant academic research and investigate materials collected from nature,” says Kati Heikkilä-Huhta, the coordinating teacher from Oulu Steiner school. The project is looking forward to continue developing courses and research projects that utilize this type of device. As of now, the Shared Light research group has used NIRis to isolate over a thousand new strains of phototrophic bacteria from a variety of plants in different seasons and locations.

“The easy detection allowed sampling of large collections and accelerated our research considerably. This is especially exciting as the prevalence of this type of bacteria in and on plants has been studied very little, especially

with cultivation-based approaches,” explains Riitta Nissinen, University lecturer from the University of Turku. “This phenomenon is highly interesting when you consider that bacteria exist within plants that also perform bacterial photosynthesis. Here, they do not produce sugars, but only chemical energy utilizing light energy,” added professor in nanosciences Janne Ihalainen from the University of Jyväskylä.

O. Franz et al.: NIRis: A low-cost, versatile imaging system for near-infrared fluorescence detection of phototrophic cell colonies used in research and education, PLoS ONE 19, e0287088 (2024); DOI: 10.1371/journal.pone.0287088

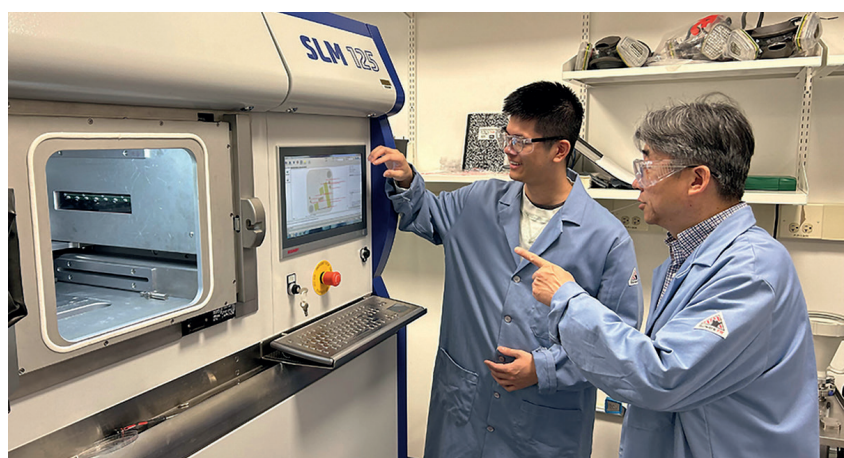
<https://www.jyu.fi/en/science/nsc>

Ultrastrong aluminum alloys for additive manufacturing

Introduction of nanoscale medium entropy intermetallics for the design of ultrastrong, deformable alloys

Purdue University material engineers have created a patent-pending process to develop ultrahigh-strength aluminum alloys that are suitable for additive manufacturing because of their plastic deformability. Haiyan Wang and Xinghang Zhang lead a team that has introduced transition metals cobalt, iron, nickel and titanium into aluminum via nanoscale, laminated, deformable intermetallics. “Our work shows that the proper introduction of heterogeneous microstructures and nanoscale medium-entropy intermetallics offers an alternative solution to design ultrastrong, deformable aluminum alloys via additive manufacturing,” Zhang said. “These alloys improve upon traditional ones that are either ultrastrong or highly deformable, but not both.”

Lightweight, high-strength aluminum alloys are used in industries from aerospace to automobile manufacturing. “However, most commercially available high-strength aluminum alloys cannot be used in additive manufacturing,” graduate student Anyu Shang said. “They are highly susceptible to hot cracking, which creates defects that could lead to the deterioration of a metal alloy.” A traditional method to alleviate hot cracking during additive manufacturing is the introduction of particles that strengthen aluminum alloys by impeding the movements of



Xinghang Zhang (r.) and Anyu Shang prepare to use a 3D printer at the Flex Lab in Discovery Park District at Purdue University.

dislocations. “But the highest strength these alloys achieve is in the range of 300 to 500 megapascals, which is much lower than what steels can achieve, typically 600 to 1,000 megapascals,” Wang said. “There has been limited success in producing high-strength aluminum alloys that also display beneficial large plastic deformability.”

The researchers have produced intermetallics-strengthened additive aluminum alloys by using several transition metals including cobalt, iron, nickel and titanium. These metals traditionally have been largely avoided in the manufacture of aluminum alloys. “These intermetallics have crystal structures with low symmetry and are known to

be brittle at room temperature,” Shang said. “But our method forms the transitional metal elements into colonies of nanoscale, intermetallics lamellae that aggregate into fine rosettes. The nanolaminated rosettes can largely suppress the brittle nature of intermetallics.”

Wang said, “Additive manufacturing using a laser can enable rapid melting and quenching and thus introduce nanoscale intermetallics and their nanolaminates.”

A. Shang et al.: Additive manufacturing of an ultrastrong, deformable Al alloy with nanoscale intermetallics, Nat. Commun. 15, 5122 (2024); DOI: 10.1038/s41467-024-48693-4

<https://engineering.purdue.edu>

The first chip-based 3D printer

Smaller than a coin, this optical device could enable rapid prototyping on the go

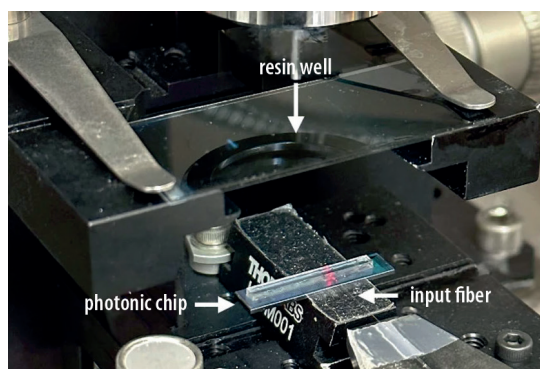


Image of the setup used for the proof-of-concept 3D-printer demonstration (Source: MIT / NPG / WIN)

Imagine a portable 3D printer you could hold in the palm of your hand. The tiny device could enable a user to rapidly create customized, low-cost objects on the go, like a fastener to repair a wobbly bicycle wheel or a component for a critical medical operation. Researchers from MIT and the University of Texas at Austin have demonstrated such a chip-based 3D printer. Their proof-of-concept device consists of a single, millimeter-scale photonic chip that emits reconfigu-

rable beams of light into a well of resin that cures into a solid shape when light strikes it.

The prototype chip has no moving parts, instead relying on an array of tiny optical antennas to steer a beam of light. The beam projects up into a liquid resin that has been designed to rapidly cure when exposed to the beam's wavelength of visible light. By combining silicon photonics and photochemistry, the chip can print arbitrary two-dimensional patterns. Shapes can be fully formed in a matter of seconds.

In the long run, they envision a system where a photonic chip sits at the bottom of a well of resin and emits a 3D hologram of visible light, rapidly curing an entire object in a single step. This type of portable 3D printer could have many applications, such as enabling clinicians to create tailor-made medical device components or allowing engineers to make rapid prototypes at a job site.

As experts in silicon photonics, the group of Jelena Notaros at MIT

previously developed integrated optical-phased-array systems that steer beams of light using a series of microscale antennas fabricated on a chip using semiconductor manufacturing processes. By speeding up or delaying the optical signal on either side of the antenna array, they can move the beam of emitted light in a certain direction. Such systems are key for lidar sensors, which map their surroundings by emitting infrared light beams that bounce off nearby objects.

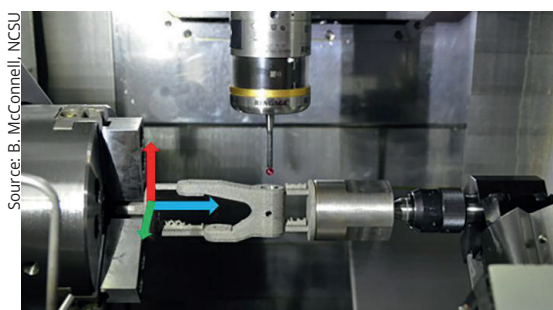
At about the same time they started brainstorming, the Page group at UT Austin demonstrated specialized resins that can be rapidly cured using wavelengths of visible light for the first time. This was the missing piece that pushed the chip-based 3D printer into reality.

S. Corsetti et al.: Silicon-photonics-enabled chip-based 3D printer, *Light: Sci. Appl.* 13, 132 (2024); DOI: 10.1038/s41377-024-01478-2

web.mit.edu/notaros/www/

Faster quality control for 3D printed machine parts

Identifying potential flaws without having to remove the parts from the manufacturing equipment



A 3D-printed part mounted in the CNC machine after finishing work; the touch probe is preparing to take automated measurements

North Carolina State University researchers have demonstrated a technique that allows people who manufacture metal machine parts with 3D printing technologies to conduct automated quality control of manufactured parts during the finishing process. The technique allows users to identify potential flaws without having to remove the parts from the manufacturing equipment, making production time more efficient.

After a metal machine part is printed, it requires additional finishing and has to be measured to ensure the part meets critical tolerances. In other words, every aspect of the part must be the right size. Currently, that involves taking a part out of the relevant manufacturing equipment, measuring it, and then putting it back into the manufacturing equipment to make small adjustments.

"This may need to be done repeatedly, and can take a significant amount of time," McConnell says. "Our work here expedites that process." Specifically, the researchers have integrated 3D printing, automated machining, laser scanning and touch-sensitive measurement technologies with related software to create a largely automated system that produces metal machine components that meet critical tolerances.

After printing, lasers scan the part to establish its dimensions. A software program then uses these dimensions

and the desired critical tolerances to guide the finishing device, which effectively polishes out any irregularities.

The researchers note that this work focuses on printing and finishing machine parts that include circles or cylinders, such as pistons. However, the approach could be adapted for machine parts with other features. "All of the hardware we used in this technique is commercially available, and we outline the necessary software in the paper – so we feel that this new approach could be adopted and put into use almost immediately," McConnell says. "And we are certainly open to working with partners who are interested in making use of this technique in their operations."

C. J. Kelly et al., Automatic feature-based inspection and qualification for additively manufactured parts with critical tolerances, *Int. J. Manuf. Tech. Manage.* 38, 236 (2024); DOI: 10.1504/ijmtm.2024.138337

<https://camal.ncsu.edu>

An optical filter improves Brillouin mechanical imaging

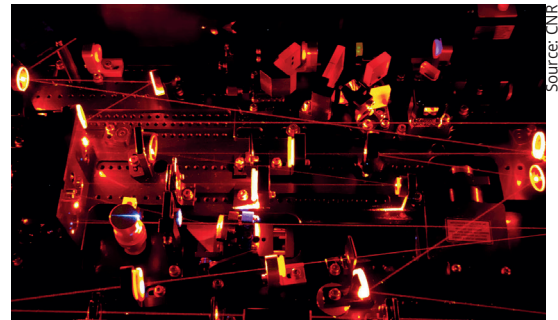
New device enables the measurement of the elasticity of subcellular structures

A team composed of researchers from the Politecnico di Milano, the Institute of Photonics and Nanotechnologies (CNR-IFN), the Institute of Genetic and Biomedical Research of the National Research Council of Milan (CNR-IRGB), the start-up Specto Photonics, also based in Milan, and Humanitas, has developed an innovative birefringent optical filter that allows for increasingly precise measurement of the elasticity of subcellular structures such as bone tissues.

Brillouin spectroscopy is an advanced optical technique that provides access to the mechanical properties of organic and inorganic on a microscopic scale and without physical contact. This noninvasive technique already has multiple uses in the biomedical field, allowing, for example, in vivo and 3D measurement of the elasticity of subcellular structures, which is crucial for studying diseases such as osteopetrosis. Despite its potential, the use of Brillouin spectroscopy is still limited today because it relies on

detecting a very weak optical signal, which unfortunately is overwhelmed by optical disturbances approximately a billion times stronger, thus hindering its detection. These disturbances are inevitably due to the light used to excite the sample and are even stronger when the material is turbid.

To overcome this obstacle, the team designed and developed an innovative optical filter, the birefringence-induced phase delay (BIPD) filter. "This extremely compact filter is capable of suppressing the strong disturbances caused by the excitation light with an unprecedented level of attenuation. Thanks to the filter, it was finally possible to acquire high-resolution images of the elastic properties of various samples where optical disturbances are usually dominant, such as bone tissues," explains Cristian Manzoni, a researcher at CNR-IFN. "The goal now is to provide a device that enables the investigation of the mechanical properties in opaque tissues, which were previously inaccessible with conventional tech-



Source: CNR

When applied to Brillouin spectroscopy techniques, the special optical filter enables the measurement of the elasticity of sub-cellular structures such as bone tissues

niques," continues Giuseppe Antonacci of Specto Photonics.

In a first test, the BIPD filter allowed the observation of significant alterations in the mechanical properties of an animal's bones on a micrometric scale.

G. Antonacci et al., Birefringence-induced phase delay enables Brillouin mechanical imaging in turbid media, Nat. Commun. 15, 5202 (2024); DOI: 10.1038/s41467-024-49419-2

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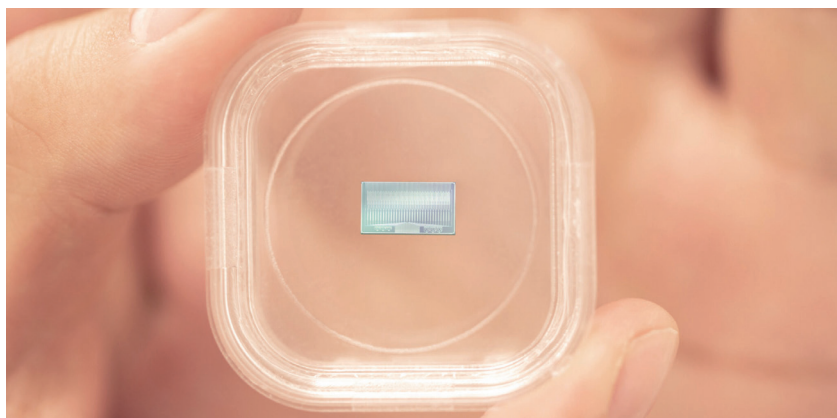
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Next-generation scanner-detector chip unveiled

Scantinel introduces photonic single chip based on standard CMOS technology



The novel photonic scanner-detector chip (Source: Scantinel)

The next-generation photonic integrated circuits (PICs) feature a fully integrated, massively parallel detector system for coherent lidar. The recently fabricated photonic chip, which includes both a scanner and detector system on a single chip, was successfully tested at Scantinel. It demonstrated a significant per-pixel improvement in

signal-to-noise ratio (SNR) of about 20 dB compared to previous solid-state lidar scanners.

This scanner-detector chip is a fully integrated, automotive-ready device suitable for automotive lidar samples that include a photonic chip and a low-noise electronics board. Due to the SNR improvements, the system has achieved

a tenfold reduction in lidar power consumption, paving the way for faster pixel rates. Compared to market systems using proprietary technology or two-mirror scanners, this generation features solid-state scanning and fully leverages the advantages of FMCW technology over existing time-of-flight (TOF) lidar systems.

The PIC production is fully transferred to high-volume standard CMOS fabrication, indicating the advanced maturity of the technology being developed.

“We believe in the efficient integration of proven technology building blocks using CMOS fabrication in combination with hybrid-packaging processes to enable highly reliable single-chip photonic lidar sensors for the automotive market,” explained Vladimir Davydenko, chief scientist and co-founder of Scantinel.

www.scantinel.com

Implantable LED device to treat cancer

Photoactivated cells exhibited signs of cell death by light-induced pyroptosis

Certain types of light have proven to be an effective, minimally invasive treatment for cancers located on or near the skin when combined with a light-activated drug. But deep-seated cancers, surrounded by tissue, blood and bone, have been beyond the reach of light's therapeutic effects. To bring light's benefits to these harder-to-access cancers, engineers and scientists at the University of Notre Dame have devised a wireless LED device that

can be implanted. This device, when combined with a light-sensitive dye, not only destroys cancer cells, but also mobilizes the immune system's cancer-targeting response.

“Certain colors of light penetrate tissue deeper than other,” said Thomas O'Sullivan. “It turns out that the kind of light – in this case green – that does not penetrate as deeply has the capability of producing a more robust response against the cancer cells.” Before the light can be effective in destroying cancer cells, a dye with light-absorbing molecules must be administered to the cells. The device turns on, the dye transfers the light into energy and that energy makes the cells' own oxygen toxic – in effect, turning the cancer cells against themselves.

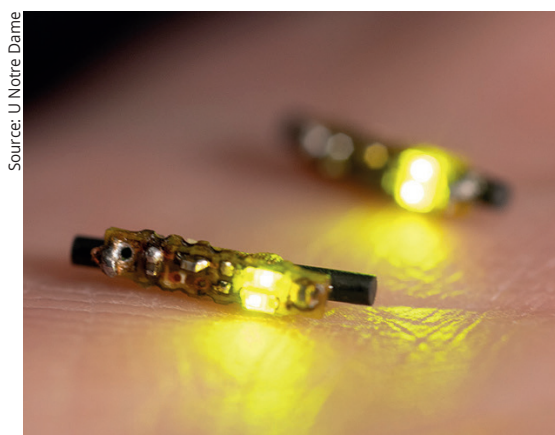
While other treatments also weaponize the cells' own oxygen, this device causes a particularly serendipitous form of cell death. “Working together, biochemistry graduate student Hailey Sanders and electrical engineering graduate student SungHoon Rho perceptively noted that the treated cells

were swelling, which is the hallmark of a kind of cell death, pyroptosis, that is particularly good at triggering the immune response,” said Bradley Smith. “Our goal is to induce just a little bit of pyroptotic cell death, which will then trigger the immune system to start attacking the cancer.”

In future studies, the device will be used in mice to see whether the cancer-killing response initiated in one tumor will prompt the immune system to identify and attack another cancerous tumor on its own. O'Sullivan noted that the device, which is the size of a grain of rice, can be injected directly into a cancerous tumor and activated remotely by an external antenna. The goal is to use the device not only to deliver treatment but also to monitor the tumor's response, adjusting signal strength and timing as needed.

S. Rho et al.: Miniature wireless LED-device for photodynamic-induced cell pyroptosis, *Photodiag. Photodyn. Ther.* 47, 104209 (2024); DOI: 10.1016/j.pdpdt.2024.104209

<https://osullivangroup.nd.edu>



This miniature, implantable LED device fights cancer with light

Source: U Notre Dame

Optical fibers for quantum computing

Optical nonlinearity provides a valuable medium for the generation of quantum resource states

A new generation of specialty optical fibers has been developed by physicists at the University of Bath in the UK to cope with the challenges of data transfer expected to arise in the future age of quantum computing. The cable networks used today to transmit information across the globe are likely to be suboptimal for quantum communications, due to the solid cores of their optical fibers. Unlike regular optical fibers, the specialty fibers fabricated at Bath have a microstructured core, consisting of a complex pattern of air pockets running along the entire length of the fiber.

“The conventional optical fibers that are the workhorse of our telecommunications networks of today transmit light

tance over which this technology can operate. Specialty optical fibers can go beyond connecting nodes of a network to implementing quantum computation at the nodes themselves by acting as sources of entangled single photons, quantum wavelength converters, low-loss switches, or vessels for quantum memories.

The fibers fabricated at Bath have a microstructured core, consisting of a complex pattern of air pockets running along the entire length of the fiber. The pattern of these air pockets is what allows researchers to manipulate the properties of the light inside the fiber and create entangled pairs of photons, change the color of photons, or even trap individual atoms inside the fibers.



Bright light guided through an optical fiber

at wavelengths that are entirely governed by the losses of silica glass. However, these wavelengths are not compatible with the operational wavelengths of the single-photon sources, qubits, and active optical components that are required for light-based quantum technologies,” said Kristina Rusimova from the department of physics at Bath. Rusimova and her colleagues describe the state-of-the-art fibers, along with other recent and future developments in the emerging field of quantum computing.

In a publication, the researchers discuss the associated challenges of the quantum Internet from the viewpoint of optical fiber technology and present an array of potential solutions for scalability of a robust, wide-scale quantum network. This encompasses both the fibers that will be used for long-range communication and specialty fibers that will allow for quantum repeaters, integrated directly into the network in order to extend the dis-

“Researchers around the world are making rapid and exciting advancements in the capabilities of microstructured optical fibers in ways that are of interest to industry,” said postdoc Kerriane Harrington. “Our publication describes the exciting advances of these novel fibers and how they could be beneficial to future quantum technologies.” Her colleague Alex Davis added: “It is the ability of fibers to tightly confine light and transport it over long distances that makes them useful. As well as generating entangled photons, this allows us to generate more exotic quantum states of light with applications in quantum computing, precision sensing and impregnable message encryption.”

C. McGarry et al.: Microstructured optical fibers for quantum applications: Perspective, *APL Quantum* 1, 030901 (2024); DOI: 10.1063/5.0211055

www.bath.ac.uk

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From classical optics to EUV, laser material processing and fusion energy

Report on the 125th DGaO annual conference 2024



Fig. 1 Group photo of the attendees of the DGaO Annual Conference 2024

The 125th annual conference of the German Society for Applied Optics (DGaO) was held from May 21 to 25, 2024 at the RWTH Aachen, hosted by Professor Dr Carlo Holly. In addition to traditional topics, the focus of the conference with the involvement of local institutes was on laser material processing, digital photonics production, and optics for and with EUV.

The 165 participants (Fig. 1) had the chance to explore Aachen's Melaten Campus on the eve of the 125th conference. They were given insights into the research conducted at the Fraunhofer Institute for Laser Technology, the Fraunhofer Institute for Production Technology, the Digital Photonic Production research campus, and the RWTH Aachen chair of digital additive production. In small groups, they observed various manufacturing machines in operation and made initial contacts. The evening concluded with light refreshments and a lecture on Aachen's architecture at the Fraunhofer Institute for Laser Technology. The rest of the conference program then took place exclusively at the main campus of the RWTH Aachen.

On the first official day of the conference, May 22, the event was opened by the DGaO president Ricarda Kafka and the conference chair Prof Holly (Fig. 2). They presented the conference program to the participants, which included 18 sessions with 83 short presentations, six main presentations, a symposium on digital photonics production, a panel discussion, the annual Fraunhofer Lec-

ture, and 23 poster presentations. Prof Holly then gave the first main presentation entitled "Data-driven innovation – connecting the real and digital world of photonics", which provided an extensive overview of current developments in digital photonics solutions in Aachen. The first six sessions then covered the topics of digital photonics production, model building and simulation, interferometry, additive manufactured optics, interferometric sensors, and applications of 2-photon polymerization. The interferometry session was opened with another main presentation by Eva Kuhn on the development of ball interferometers at the Physikalisch-Technische Bundesanstalt (PTB). After numerous presentations and discussions, the first day ended with a poster session with snacks and drinks.

The second day of the conference was initiated by the two main presenta-

tions of Prof Dr Anne Harth and Marco Hanft. While Professor Harth spoke about the creation of attosecond pulses, fitting with the recently awarded Nobel Prize, Marco Hanft presented his strategy for dealing with new trends in the development of optical systems. These were followed by five sessions on topics such as optics for and with EUV, optics design, measurements and characterization of nanostructures, design methods and strip production, and a panel discussion on career perspectives in optics and photonics. Subsequently, the DGaO Young Scientist Awards were awarded to Tim Käseberg (PTB Braunschweig) for his doctoral thesis entitled "Optical metrology for resolving topological information of nanoscale structures using modified müller-matrix ellipsometry" (Fig. 3 left), and to Johannes May (TU Ilmenau) for his diploma thesis on "Construction of a phase-modulated sideband interferometer for holographic vibration measurement" (Fig. 3 right). The certificates were presented by Ricarda Kafka and Prof Dr Andreas Heinrich, head of the prize committee. For the evening program, participants could choose between a scavenger hunt or a guided tour of Aachen's historic city center. This was followed by networking and dinner at the Ratskeller in the Aachen City Hall, a charming historical setting.

The research activities of the Aachen research institutes were the focus of the symposium and the Fraunhofer lecture the following day, in addition to sessions on diffractive optical elements,



Fig. 2 DGaO opening welcome by Ricarda Kafka and Prof Dr Carlo Holly



Fig. 3 DGaO Young Scientist Award winners Tim Käseberg (left), and Johannes May (right), with Ricarda Kafka and Prof. Andreas Heinrich, respectively

optical system design, 3D metrology, and innovative camera concepts. During the symposium, scientists from academic and industrial fields provided detailed insights into optical sensing for laser material processing (M. Kogel-Hollacher, Precitec), the use of differentiable neural networks (DNNs) for effective laser beam shaping (P. Buske, TOS, RWTH Aachen), and precise laser marking through synchronized cascading (H. Schlüter, Scanlab). The lecture by Paul Buske on the use of DNNs in particular generated great interest and led to lively discussions.

After the symposium and the sessions, the DGaO General Meeting took place, resulting in the election of a new board, the re-election of Ricarda Kafka as DGaO president, and the official handover of the organization of next year's DGaO conference in Stuttgart to Prof. Dr. Stephan Reichelt. The Fraunhofer Lecture was delivered in the evening by

Prof. Dr. Constantin Häfner, managing director of the Fraunhofer Institute for Laser Technology. He shared insights into the Fraunhofer-Gesellschaft's initiatives to advance laser-based inertial fusion in Germany. The evening was rounded off at the Auditorium Carolina with the gala dinner, during which the poster prizes were awarded to Julian Wüster (1st place), Andrea Rüdinger (2nd), and Christian Schober (3rd).

On Saturday morning, two main presentations kicked off the last day of the DGaO conference and the last two sessions on optical metrology and laser material processing. PTB president Prof. Dr. Cornelia Denz first provided an excellent overview of PTB's work in optical precision technology for the realization of a digital, safe, and sustainable world. This was followed by Jens Gottmann's report on 3D precision structuring of glass by selective laser-induced etching and UKP laser welding.

The 125th DGaO Annual Conference was a great success. The event provided a variety of high-quality lectures, interesting sessions, and discussions, providing participants with valuable insights and new knowledge in the field of applied optics. The range of topics covered and the exceptional quality of the contributions made for a stimulating and rewarding conference experience. The opportunity for networking and exchanging ideas with colleagues from different fields also provided valuable opportunities for networking and collaboration.

The conference's success can be attributed to the proficient organization and dedicated organizing team, particularly the conference leadership under Prof. Holly and Nicole Grubert, the program committee led by Prof. Dr. Christian Faber, and the DGaO secretariat under Katja Richter.

Dr. Ulrike Boehm

Spectaris general meeting sets course for future work

Fresh air in the re-elected and proven leadership team of the German industry association

New board members were elected at this year's general meeting of the German industry association Spectaris on September 18. This election of seven board members brings both continuity and a breath of fresh air to the association's leadership, according to chairman Dr. Bernhard Ohnesorge.

Christoph Miethke, managing majority shareholder of the medical technology company of the same name, was newly elected to the board. He holds the office of chairman of the Berlin / Brandenburg region, where he is already active in various honorary positions in business organizations. The other six board positions were filled by the current members.

André Schulte, CEO of Weinmann Emergency Medical Technology, was re-elected as deputy chairman. Mathis Kuchejda, chairman of the association of analytical, bio and laboratory technology, and managing director of analytical equipment manufacturer Schmidt + Haensch, continues as treasurer.

Dr. Sebastian Braun-Lüdicke, who just took up a management position at Aesculap, was confirmed as chairman of the Baden-Württemberg regional group. The Rodenstock COO Roland Dimbath remains chairman of the Bavarian regional group.

Carl Zeiss Meditec CFO Justus Wehmer remains chairman of the Mecklenburg-Western Pomerania, Thuringia,



Newly elected board member Christoph Miethke (2nd from left), with re-elected Mathis Kuchejda, André Schulte, and Roland Dimbath (Source: Spectaris)

Saxony-Anhalt, and Saxony regional groups. Friedrich Schmitz of Schmitz Medical was re-elected as chairman for the North Rhine-Westphalia region.

www.spectaris.de

Leadership changes at Optica

Former CEO and executive director of the Optica Foundation are no longer with the society

In his October President's Message, Gerd Leuchs, current society president and former director of the Erlangen, Germany, Max Planck Institute for the Science of Light, announced the departure of Elizabeth Rogan, who served as Optica CEO, and Chad Stark, formerly the executive director of the Optica Foundation.

According to media reports and US Congress statements, the departure followed months of investigations by Bloomberg and scrutiny by the US Congress Science Committee leaders regarding "anonymized donations to recipients of prestigious research

awards". As Bloomberg summarizes, a US-sanctioned Chinese company "secretly backs US research, awarding millions [of US dollars] in prizes." According to the report, Optica decided in June to return the funds that the Chinese company had committed to the research competition and to remove the company's representation on the judges' panel.

Leuchs states that "in the course of the independent review that the Optica board of directors undertook, no violation of law was identified. However, it was determined that not all of the

agreed controls associated with the program were implemented, and there was a lack of transparency with the Optica Foundation board."

As part of the leadership changes, the Optica board of directors has asked Elizabeth Nolan to serve as Optica CEO and executive director of the Optica Foundation on an interim basis. She had been deputy executive director and chief publishing officer for over a decade.

On October 11, the board of directors named Nolan CEO of Optica. (Sources: Bloomberg, US Congress, Optica)

New addition to Optica's Board of Directors

Christine P. Hendon and Turan Erdogan elected by the society's members



Christine P. Hendon (l), Turan Erdogan

The 2024 election results were announced at the Optica Annual Business Meeting.

Turan Erdogan was elected as 2025 vice president of Optica. He currently serves as the president of Plymouth Grating Laboratory, Inc. (PGL) in Carver, Massachusetts, the leading com-

mercial supplier of diffraction gratings for pulse compression of ultrahigh-intensity lasers for high-energy-laser and spectral-beam combining, as well as laser applications. "Turan is an accomplished leader. From his significant volunteer service with Optica, to his time on the faculty of the University of Rochester, and his corporate leadership at Melles Griot, IDEX, and PGL, he has shown an incredible ability to effectively work with both academia and industry while simultaneously supporting the optics and photonics community," said Optica CEO Elizabeth Nolan.

Christine P. Hendon of Columbia University was elected as the 2025–2027 director-at-large. She is an associate professor of electrical engineering, director of the Structure Function Imaging Laboratory, and vice dean of diversity and strategic partnerships within Columbia's engineering school. She teaches optical systems and digital image processing to a diverse student population. Her research contributions include optical systems and methods to extract architectural information and identify structural substrates within tissue.

www.optica.org

Orbis Diagnostics CEO elected into SPIE presidential chain

Cather Simpson is the society's next vice president



(l-r, top row) Cather Simpson, Jim McNally, Alexis Vogt, (l-r, bottom row) Debbie Gustafson, Brian Pogue, Kishan Dholakia (Source: SPIE)

The University of Auckland professor and Orbis Diagnostics CEO Cather Simpson has been elected to serve as the 2025 vice president of SPIE. She will serve as president-elect in 2026, and as the society's president in 2027. The 2024 president Jennifer Barton made the announcement along with other election results at this year's annual general meeting during SPIE Optics+ Photonics.

Alongside Simpson, Zygo Corporation's Peter de Groot will serve as the 2025 SPIE president while University of Rochester professor Julie Bentley will

serve as president-elect. Jim McNally, CEO of StratThnk Associates, was elected to serve as the 2025 SPIE secretary and treasurer.

The following newly elected society directors will serve three-year terms from 2025–2027: Alexis Vogt, professor of optics at Monroe Community College and an executive director at AmeriCOM, Debbie Gustafson, CEO of Energetiq Technology, Brian Pogue, professor at the University of Wisconsin-Madison, and Prof Kishan Dholakia, University of Adelaide.

<https://spie.org>

Micro is the new black

A review of EPIC technology meetings in Salzburg, Noordwijk, and Vilnius



Source: EPIC

Participants at the EPIC Technology Meeting on Photonics for Miniaturized Optics visited the facilities at Sony DADC, Salzburg, Austria

Micro-optics is rapidly gaining traction in large-scale markets, as demonstrated during a two-day meeting held at Sony DADC in Salzburg, Austria. With twenty-two speakers, the event emphasized the vast potential of miniaturized optics as well as the strides being made to scale the technology for widespread commercial use. The discussions highlighted that miniaturization is not just a trend but a critical innovation for transforming industries like medical devices and consumer electronics. Key topics included the applications of miniaturized optics, challenges in manufacturing, advancements in micro

and nanoscale optics, and solutions in design and simulation.

Earlier, EPIC members met at the European Space Agency (ESA) facilities in Noordwijk, Netherlands, for a meeting discussing the role of photonics in space communications. The event tackled some important technological challenges and worked on defining a roadmap for New Space optical communication technologies, from ground-to-ground to space-to-space communications. The discussions also focused on how innovation in photonics intersects with geostrategy and sought to foster stronger col-

laboration between ESA and European companies by addressing practical considerations for working with the space agency.

In Vilnius, Lithuania, EPIC members gathered to discuss laser micromachining, an essential technology for producing components used in optical communication systems. This meeting centered on the latest applications, future challenges, and emerging needs in laser micromachining. The event instigated some dynamic discussions and enabled productive networking opportunities among participants.

<https://epic-photonics.com>

Save the date for EPIC upcoming events:

- 2 December 2024
EPIC Technology Report on Photonics in AI & AI in Photonics by Bruce Bateman, Online Event
- 3 – 4 December 2024
EPIC Technology Meeting on Photonics Technologies for Medical Diagnosis and Treatments at ICFO Barcelona, Spain
- 6 December 2024
EPIC Sustainability Workgroup Meeting
Online Event
- 9 December 2024
EPIC Online Technology Meeting on Photonics for New Display Technologies
Online Event
- 13 December 2024
EPIC HR Workgroup Meeting:
Transition of New Executive Management
Online Event
- 13 January 2025
EPIC Online Technology Meeting on Photonics for Quantum Industry
Online Event
- 27 January 2025
EPIC SUMMIT on Optimizing and Scaling Photonics Manufacturing
San Francisco, CA, USA
- 28 January 2025
EPIC VIPs Networking Lunches and Reception
San Francisco, CA, USA
- 28 January 2025
EPIC Members Networking Reception in San Francisco
San Francisco, CA, USA
- 28 January 2025
EU Projects & Innovation Hubs Breakfast
San Francisco, CA, USA
- 29 January 2025
EPIC Executive 5 Miles Run in San Francisco
San Francisco, CA, USA
- 30 January 2025
EPIC Members Run in San Francisco
San Francisco, CA, USA

For the list of all events, visit:



<https://epic-photonics.com/epic-events>

"We switched from nano to femtosecond lasers and never looked back"

Axel Kupisiewicz, founder and CEO at Lasea and Stéphane Bussa, CCO of the Lasea group, talked to EPIC's technology manager Antonio Castelo

Lasea is a provider of laser micromachining, plastic welding, marking and traceability, and surface treatment for the medical, watchmaking and jewelry, electronics, and R&D sectors. Its CEO and CCO were interviewed by EPIC's technology manager for biomedical and lasers.

Axel, what is the background to you founding Lasea as CEO?

Axel Kupisiewicz: After completing a degree in engineering and then a master's in economics at the University of Liège, I worked as an engineer at the Liège Space Center where I was involved in developing a laser cleaning process to remove the coatings of satellite mirrors. I saw the opportunity to develop a business in the fields of laser coating removal and laser cleaning, and so in 1999 I set up Lasea in my garage.

How has the company developed?

AK: I started by patenting and selling layer removal applications, and in 2000 I launched the first laser industrial process for installation in production lines to remove layers from coated glass for windscreens. It was very challenging because I was on my own at the time, so I had to find some partners to manufacture the production line equipment, which I successfully sold to major glass manufacturers in Europe and Japan.

Then I was asked to do other things like plastic welding and laser marking. I was surprised how old fashioned the technology was at that time, for example using glue for plastic welding, acid baths to microcut components, and a high energy consumption milling center for micromachining. Laser welding processes and laser micromachining



Source all images: Lasea

Lasea CEO and founder Axel Kupisiewicz

were much cleaner, easier to use, and used a lot less energy – so I saw it as not only a business opportunity, but also an opportunity to do something useful for the environment and society.

In 2004 we participated in the EU-funded NAGINELS project and began selling traceability and anticounterfeiting applications to the pharmaceutical industry. We then developed plastic welding, marking, layer removal, and cutting production lines for the automotive and food industries.

But the key landmark in our history was the 2011 Laser Munich show where we presented the first micromachining workstation that incorporated Amplitude's Satsuma femtosecond lasers. At that time there were only eleven of us,

but after this event we grew by thirty percent each year and we now have a workforce of two hundred.

In 2012, we set up Lasea France to specialize in micromachining, and in 2016, we created Lasea United States. In 2017, we established Lasea Switzerland and acquired WOW, a leader in the development of automated solutions in Belgium. In 2020, we acquired Optec, a manufacturer of femtosecond and excimer laser machines specific to the medical and electronics sector. In the same year, Lasea relocated to a new 3,500 m² building in Liège, and in 2022 we acquired the French company Laser Cheval, since when the Lasea group has become the number 1 in laser micromachining in Europe.

What challenges did you have in expanding your workforce?

AK: Growing at thirty percent each year has meant increasing the workforce by one third annually. So since 2011, we have had to double the team every three years, train them and move to a new plant twice as big.

What was your main criteria for the acquisitions?

AK: Of course, we have a formula for evaluating the strategic, financial and human resource advantages of an acquisition, but for me the most important factor is that the culture of the company needs to be compatible with Lasea's.

How important have femtosecond lasers been to your success?

AK: Very much so. The first systems we sold to universities were scientific lasers, which were unreliable. The big change was in 2011 when we incorporated Amplitude's Satsuma femtosecond lasers in our first industrial systems. These lasers proved to be far more reliable for 24-hour operation and only require one preventive maintenance, so we switched from nano to femtosecond lasers, and we have never looked back.

How important are EU projects like NAGINELS for the industry?

AK: Technological readiness is rather low in Europe, and EU funding is very important for the future of European competitiveness and industrialization. R&D is very costly, and when you are a small company or a startup with a limited R&D budget, it is impossible to develop new kinds of technology and cutting-edge applications without

financial support from the EU. It is not about being able to develop a product that you can put on the market today – it is more about preparing to push the boundaries so that in a few years we can develop new applications like biomimetics and compete with the giants in the US and China.

Stéphane, what were your personal challenges when you joined Lasea?

Stéphane Bussa: I have known Axel for 25 years. When he started Lasea, I was working for Thales selling lasers to him for his cleaning processes. Rather than a challenge, joining Lasea in March 2024 was an exciting adventure because I saw it as an opportunity to make it a more effective and efficient company – manufacturing laser machining systems with a much more standard approach and pushing our machines onto the market. So it is all about market intelligence, product marketing and more accurate sales processes.

How do you see the future?

SB: We are turning Lasea into a company that designs and delivers industrial standard machines for the key verticals that we have identified. We will always keep an eye on our partner universities because we want to continue to pioneer applications such as biomimetics. The laser is all about the interaction between light and materials and the big added value of a company like Lasea is our knowledge of this interaction: how to use the laser, the type of parameters, and what kind of jobs can be done on a machine. In this context, we are designing our own range of specially designed modules that can quickly and easily be integrated into our workstations or into our customers' specific environments. We also own 120 patents in thirty families that we want to leverage, so we have a lot to do.

Another of our challenges is to develop Lasea out of Europe. We have had a subsidiary in the US since 2016 and we intend to invest massively in the coming years to develop business in the Americas. We are also exploring the market in Asia where we have a lot of inquiries. We could develop in so many



The neo 1 from Lasea

directions because the market is huge and the requirements are enormous, particularly for photovoltaics, batteries for automation, and aeronautics. A lot of electronic applications providers are now willing to use ultrafast lasers. Ultimately, the challenge for a company of two hundred people with a yearly growth of thirty percent is to focus on where we think we can really make a difference.

Axel Kupisiewicz: What is very nice in our field are the opportunities that appear thanks to the increasing power of the laser. Although we have stayed focused on the luxury, MedTech, electronics and R&D sectors, thanks to the increase in power, each year we have gone into the new markets of thin layer laser ablation, cutting, drilling, engraving, and surface structuring. But there are many other markets such as aerospace, defense, and biomimetics – i.e., reproducing the structure of shark skin on aircraft wings to improve aerodynamics, or that of a lotus leaf to make the surface hydrophobic, or copying the tips of gecko legs that make them adhesive.

*

Dr. Antonio Castelo-Porta, EPIC – European Photonics Industry Consortium, 17 Rue Hamelin, Paris, France; e-mail: antonio.castelo@epic-photonics.com, Web: www.epic-photonics.com



Stéphane Bussa

Company

Lasea

Lasea has been a pioneering figure for more than twenty years, and is a partner for the design and manufacture of femtosecond laser micromachining tools. It designs innovative solutions with an unparalleled level of precision thanks to its expertise, research, and unique project management. Its laser machines are equipped with lasers and automation features that perfectly complement the application and meet the required quality and safety criteria.

www.lasea.com

Raman spectroscopy and imaging in bio and life sciences

Latest developments and their applications in healthcare, biology, and biochemistry

Antonio Castelo-Porta



Raman spectroscopy is a well-known technique to study different materials and determine their chemical composition. It is based on the inelastic scattering of light and provides a unique spectrum for the sample under study. The advances in lasers and detectors, their combination with imaging systems and the discovery of new phenomena have expanded the use of this technique in several research fields. In the particular case of biology and life sciences, it has been used to provide chemical and compositional information on plant and animal tissues, cells, biofluids, etc., with the advantage that the presence of water molecules normally does not cause interference in the measured signal.

Raman spectroscopy provides a nondestructive and high-throughput evaluation of the results. It relies upon inelastic scattering of photons, known as Raman scattering, when they are excited by a monochromatic light. This illumination light interacts with molecular vibrations, phonons or other excitations in the system, resulting in the energy of the photons being shifted up or down. This shift in energy gives information about the vibrational modes in the system, and the detected spectrum provides a structural

fingerprint by which molecules can be identified. The technique has a lot of interesting advantages: it is relatively inexpensive, does not require sample preparation, and requires minimal background training. All these characteristics make it a technique with great potential for clinical and bio applications.

Portable and handheld Raman-based detection systems are used as point-of-use instruments for the identification of different compounds in the pharmaceutical industries, to detect impurities

▲ **Fig. 1** Waveguide-enhanced Raman spectroscopy sensor for bioprocess analysis (Source: InSpek)

or low-grade precursors, and for anti-counterfeit applications in the clinic or in the field. The **Wasatch Photonics** company has developed their X series for Raman spectroscopy, an extremely sensitive, highly configurable line of compact Raman spectrometers and systems designed to be used as point-of-use devices or to be integrated into

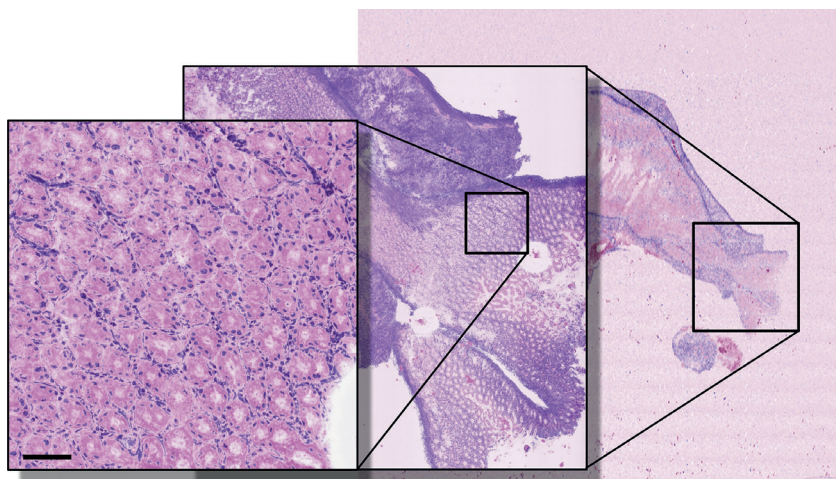


Fig. 2 Label free virtual H&E of a stomach (Source: Refined Laser Systems)

more complex Raman systems. The series includes modular spectrometers, integrated lasers, complete Raman spectroscopy systems and OEM modules working at wavelengths of 532, 638, 785, 830 and 1,064 nm, and with a resolution $<10 \text{ cm}^{-1}$ and measurement times ranging from 10 ms to 2 s. Wasatch Photonics is working now in the development of a new handheld Raman system, an even more compact spectrometer line with comparable sensitivity. These systems have been used successfully to identify disease states in biofluids, quantify glucose levels in-vivo, in biosensors, and for pathogen detection, particularly when used in conjunction with chemometric analysis.

Enhancing the Raman scattering signal

One of the historical disadvantages of Raman spectroscopy has been the low intensity of the Raman scattering signal at certain wavelengths. In those cases, a long time duration measurement may be required to obtain an acceptable signal-to-noise ratio (SNR). In addition, most biological samples have a

high background fluorescence, which further reduces the SNR of the Raman spectrum. To complement the many improvements in hardware sensitivity over the years, various Raman signal enhancement methods have been studied, such as surface-enhanced Raman spectroscopy (SERS), stimulated Raman spectroscopy (SRS), time-gated Raman spectroscopy or waveguide-enhanced Raman spectroscopy (WERS).

The interference of the background fluorescence with the Raman signal is particularly important when analyzing biological samples and specimens. It can degrade the quality of the data collected and, in some cases, obscure the spectrum entirely. Time-gated Raman spectroscopy has been shown to be an effective technical solution for this major problem. In this technique, precise synchronization between the pulsed laser excitation source and the sensitive and fast detector (through a delay generator) is mandatory to ensure the correct detection of the Raman signal. As the fluorescence emission has a longer delay, this signal is rejected during the detector dead time [1].

Organization

EPIC – European Photonics Industry Consortium

EPIC is the world-leading photonics industry association representing more than 800 members across 35 countries. EPIC promotes the sustainable development of organizations working in the field of photonics. EPIC fosters a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement. EPIC publishes market and technology reports, organizes technical workshops and B2B roundtables, supports EU funding proposals, advocacy and lobbying, education and training activities, standards and roadmaps, and pavilions at exhibitions.

www.epic-assoc.com

Meet us at Medica / Compamed 2024, Hall 8A, Booth F35



Fig. 3 Raman system to assess soft tissue resection margins

Several small and affordable time-gated Raman spectroscopy systems are available nowadays, thanks to the development of compact laser sources with suitable characteristics. The Finnish company **Picophotonics** has developed several Q-switched single-frequency ($<0.10 \text{ nm}$) laser sources suitable for this application, using their in-house developed semiconductor-based absorber technology (SESAM) for passive Q-switching. This technology enables significant pulse width reduction. The laser architecture is scalable in power and can deliver pulse durations as short as 50 ps, repetition rates of up to 200 kHz, pulse energies of several μJ , and emission at 532 nm and 1,064 nm.

Bio applications of waveguide-enhanced Raman spectroscopy

WERS is a powerful analytical technique that utilizes integrated photonics for chemical and biological sensing [2]. In its more standard configuration, a sorbent material acts as the top cladding of the waveguide core to concentrate analyte molecules in the evanescent field. As the laser propagates down the waveguide, it continuously interacts with analyte molecules that emit Stokes-shifted Raman light, which is recollected into the guided modes of the nanophotonic waveguide. This waveguide-enhanced configuration maximizes light-matter interactions, significantly amplifying the Raman signal while reducing laser power requirements.

The French company **InSpek** has taken advantage of the properties of the WERS technique to develop highly compact, robust, and efficient spectroscopy solutions capable of real-time and in situ measurements. InSpek's sensors utilize waveguides to confine and guide light at the surface of chips, maximiz-

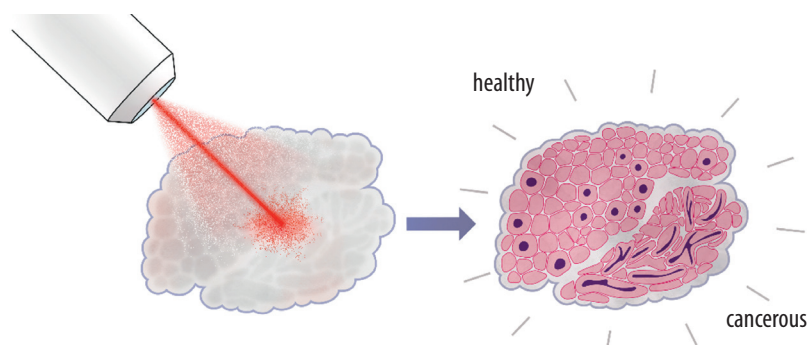


Fig. 4 Scheme of the stimulated Raman scattering (SRS) process (Source: Refined Laser Systems)

ing the light-matter interactions and significantly amplifying the Raman signal while reducing laser power requirements. Their waveguide-enhanced Raman spectroscopy systems are specifically tailored for real-time monitoring of biochemical processes in industries such as biopharma and synthetic biology. Their technology incorporates photonic integrated circuits (PICs) into Raman spectroscopy, allowing for unprecedented miniaturization, sensitivity, and cost-efficiency (Fig. 1).

InSpek's sensors can be easily integrated into bioprocessing equipment and lab environments. It is possible to detect low-concentration molecules and subtle biochemical changes due to their increased interaction between the guided light and the sample. This is particularly beneficial in bioproduction, where real-time monitoring is critical to optimizing yield and quality. The scalability of PIC production also allows for lower costs, making InSpek's sensors compatible with the single-use systems used in the biopharmaceutical industry.

Applications in oncological surgery

Raman spectroscopy has been applied ex vivo and in vivo to address various

biomedical issues, such as the detection and analysis of cancer tissues, the monitoring of the effect of various agents on the skin, or the rapid identification of pathogenic microorganisms. In the particular case of cancer detection, Raman shows great advantages in the assessment of tumor resection margins. Although different nonsurgical treatments for cancer such as chemotherapy or radiation therapy are being used nowadays, surgery is still the mainstay treatment for tumors. Its objective is the resection of all malignant tissue with a sufficient resection margin – the smallest distance between the tumor border and the resection cut surface – while preserving the maximum amount of healthy organ or tissue structure to ensure its subsequent functionality. Unfortunately, subsequent final pathological analysis of the excised tissue, days after the operation, often reveals tumor in or too close to the resection surface. That means that tumor has also been left behind in the patient, negatively affecting chances of survival and requiring adjuvant treatment such as chemotherapy or radiotherapy. Surgeons and pathologists agree that achieving adequate resection margins is critical to ensure disease control and patient survival.



Fig. 5 Refined Laser Systems' intraoperative microscope prototype for the identification of tumor margins in the surgery room (Source: Refined Laser Systems)

In order to solve this need of the medical community, the **RiverD** company has been working on the development of a dedicated Raman spectroscopic device for assessment of tumor resection margins on the resected tissue. Their prototype MarginGuide system (Fig. 3) employs a thin fiber-optic needle to measure the distance between the resection surface and the tumor, based among other on the water concentration in the tissue. It takes only a few seconds per measurement location, which will enable a thorough examination of all resection surfaces, while the patient is still in the operating room. The MarginGuide system will report the locations of incomplete tumor resection, providing the surgeon with the option to remove additional tissue in order to achieve a complete resection. A validation study has been performed for its application in oral cavity cancer surgery, which is unfortunately notorious for a very low percentage of complete tumor resections.

Identification of tumor margins with Raman microscopy

Raman imaging has become a very popular technology for the characterization of large-scale devices, the mapping of different compounds, and dynamics study. It is built upon the combination of two powerful analytical techniques, Raman spectroscopy and microscopy, as a label-free and chemical-specific microscopy technique. Based on this combination, the **Refined Laser Systems** company has developed an intraoperative microscope as another alternative to identify tumor margins directly in the surgery room. The goal is to provide pathologists and surgeons within minutes an image of tissue with sufficient contrast for clinical decision-making during surgical procedures. The Refined Laser Systems device is based on a nonlinear variant of Raman scattering called stimulated Raman scattering (SRS). This third-order nonlinear phenom-

enon involves a second light particle called the Stokes photon, which stimulates a specific transition. When the difference in frequency between both photons resembles that of a specific vibrational – or rotational – transition, the occurrence of this transition is resonantly enhanced.

The SRS technique can speed up image acquisition by a factor of a thousand, potentially enabling its use for intraoperative assessments. It has already been shown that SRS can provide label-free contrast to differentiate between cell nuclei and cell bodies, two key features of currently applied H&E-based histopathology. By quantifying the ratio of CH_2 and CH_3 chemical bonds found in cell bodies and nuclei respectively, microscopic images of healthy and cancerous tissue sections can be generated in near-perfect concordance with standard histology. In order to move from the complex laboratory setups used in previous studies to a more compact and integrated solution, Refined Laser Systems has been working on their fiber-based laser technology to develop a system for the application of SRS in the field and with a rapid and wide tuning capability for the analysis of complex samples. With Refined Laser Systems laser technology, it is possible not only to generate histological images, but also to efficiently access the entire Raman spectrum as a source of novel biomarkers and thus establish new biomarkers that, for example, could predict the outcome of immunotherapies. This innovative Raman-based diagnostic platform brings the power of multi-dimensional tissue analysis directly to the patient's bedside. By utilizing the full vibrational spectrum of tissue samples, this technology can deliver rich histological data without the need for invasive procedures or extensive lab processing.

Cambridge Raman Imaging has been pursuing a similar approach to develop their coherent Raman platform 'CORAL' system, a multimodal, label-free imaging platform offering subcellular resolution suitable for biological, biomedical, and pharmaceutical applications. This platform enables the capture of high-resolution images leveraging broadband stimulated Raman scattering (SRS) in the CH-stretching region ($2,800 - 3,100 \text{ cm}^{-1}$). The system integrates Cambridge Raman Imaging's advanced

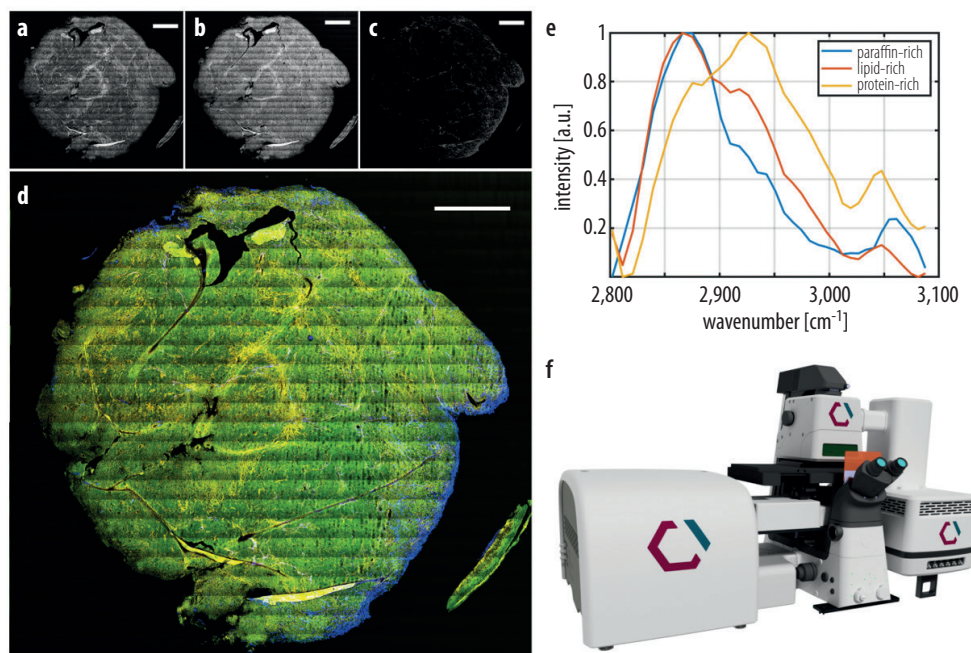


Fig. 6 Dewaxed FFPE human tissue images, spectral data, and the CORAL microscopy system: (a) Raman image highlighting paraffin at 2857.42 cm^{-1} , (b) Raman image showing protein signals at 2942.72 cm^{-1} , (c) second harmonic generation image, (d) multiplex stimulated Raman scattering (SRS) image, obtained by overlaying the images from (a), (b), and (c) in RGB format, (e) average SRS spectra from regions in (d), (f) 3D-rendered model of the CORAL commercial system. Scale bars: 1 mm

laser architecture, which passively synchronizes two fiber oscillators with an ultralow-noise multichannel detector, specifically developed for this application, in a multiplex SRS microscopy setup. Their laser delivers both picosecond and femtosecond dual-output pulse durations, facilitating access to a broad range of non-linear optical microscopy techniques, including TPEF, SHG, and pump-probe. The multichannel detector is a lock-in amplifier spectrometer engineered for single-shot CH-stretching detection across the $2,800$ to $3,100 \text{ cm}^{-1}$ range, offering 38 spectral channels, each with independent lock-in amplifiers. This capability enables the system to disentangle the paraffin contribution from that of the lipids, which overlap in this region, allowing imaging of not only fresh frozen samples but also FFPE samples. Its compact design allows real-time average power and demodulated signal extraction in parallel on all channel. Additionally, the system collects two more signals – TPEF and SHG – simultaneously through Epi-detection, supplementing the 38 channels collected by the multichannel lock-in amplifier, thereby providing comprehensive information on the organic samples under analysis. With this integrated solution, Cambridge Raman Imaging can deliver detailed images across various cytological and histological sample types.

Conclusion

Raman spectroscopy is a noninvasive technique that provides highly specific information about the molecular structure and biochemical composition of analytes in a rapid and accurate manner. It is a very interesting technology for applications in biomedicine and biochemistry. On the one hand, the possibility of integrating this technology into small and compact sensors makes Raman spectroscopy a very interesting solution for in-situ characterization of biological and chemical products. On the other hand, Raman spectroscopy and imaging can offer interesting advantages over other traditional methods used in clinical medicine. One very interesting example in oncology is the identification of tumor cells within a sample and the assessment of tumor resection margins, which can help pathologists and surgeons by dramatically reducing the analysis time, patient stress and healthcare costs.

*

Dr. Antonio Castelo-Porta, EPIC – European Photonics Industry Consortium, 17 Rue Hamelin, Paris, France; e-mail: antonio.castelo@epic-assoc.com, Web: www.epic-assoc.com

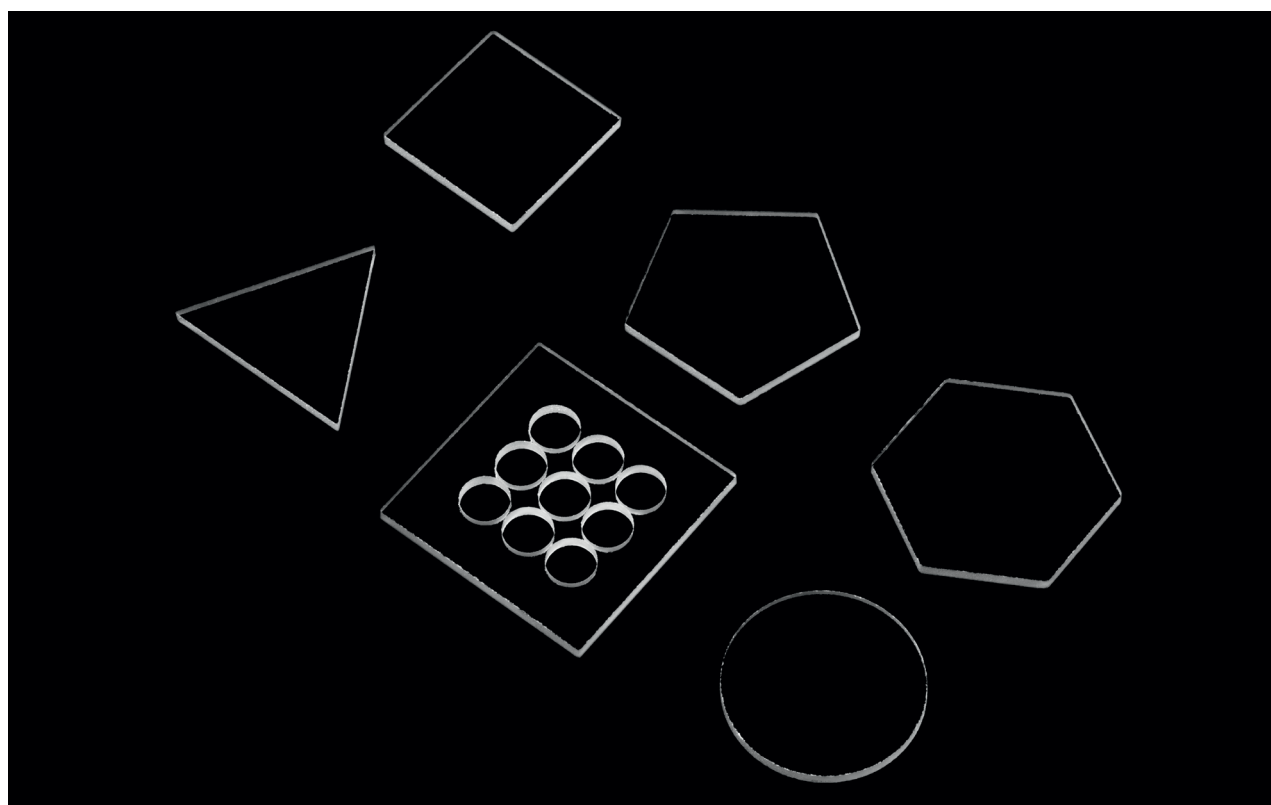
DOI: 10.1002/phvs.202400039

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Glass machining technology with a nanosecond-pulsed infrared laser

Efficient treatment for glass drilling and sanding with a flexibly designed fiber laser

Mason Zhang, Yaron He, and Hanan Huang



Source all images: Shenzhen JPT Opto-electronics

Traditional machining methods for glass drilling use contact-based processes such as CNC, grinding wheels, or chemical etching, which easily cause surface microcracks, poor quality, or environmental pollution. Additionally, traditional glass sandblasting requires complex steps involving sandblasting and UV curing. Laser processing of glass instead is more efficient, environmentally friendly, and reliable.

Glass, with its extensive use over thousands of years, has been widely used in industrial substrates, display panels, civilian glass, electronic covers and other applications due to its properties of optical transparency, surface cleanliness, high hardness, and corrosion resistance. Glass does not meet some requirements until it has been machined by various processing steps, such as drilling and sandblasting. The nanosecond infrared laser with advantages of efficiency, cost, and size, can generate higher single pulse energy

and peak power, which effectively overcomes the conventional problems and is becoming a powerful tool in glass processing.

Laser processing technology focuses the beam on the surface of objects, and uses the high energy density of the focused spot to gasify or melt the material being processed. It has the following advantages: 1. non-contact processing, which eliminates reintroduced pollution or damage, 2. higher accuracy, and 3. good processing flexibility: it can be applied to design and process irregular

shapes or patterns. With the development of high peak power laser technology, the processing technology of nanosecond pulse infrared laser with high peak power has shown great potential in improving glass manufacture processing. This paper will provide a deep introduction to both glass drilling and glass sandblasting applications using nanosecond pulse infrared lasers with a high peak power.

Glass made of different materials will be affected differently by laser processing. The speed of laser ablation



Fig. 1 (a) Filling toward inner edge, (b) filling toward outer edge, (c) underside of the glass

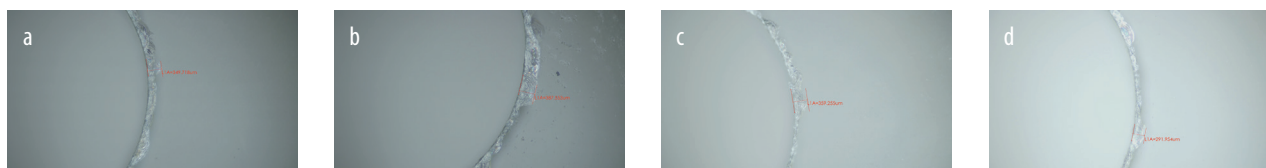


Fig. 2 Chipping edge of the glass upper surface with four pulse widths: (a) 9 ns, (b) 12 ns, (c) 14 ns, and (d) 20 ns

is related to the thermal expansion coefficient of the material. Soda-lime glass, ultraclear glass, and K9 glass are relatively easy to drill using lasers. These types of glass primarily consist of 70 % SiO_2 and contain alkali oxides with a thermal expansion coefficient ranging from 80 to $100 \times 10^{-7} \text{ }^\circ\text{C/m}$, which makes them suitable for laser drilling. However, high borosilicate glass and quartz glass with a very low thermal expansion coefficient of only $5.8 \times 10^{-7} \text{ }^\circ\text{C/m}$ are only suitable for small hole processing. It is important to note that tempered glass will shatter if any damage occurs due to its internal stress, and it is therefore not suitable for laser processing.

Laser drilling

When performing laser through-hole drilling, the laser beam is focused under the glass and slowly rises in a spiral shape. During this period, the laser will heat and vaporize the glass according to the designed path. Compared to an opaque material that can only be drilled from top to bottom, the bottom-up drilling method for transparent glass has almost no taper and ensures high consistency of through-holes. However, we can change the setting of the laser in order to change

the processing result, as shown in Figs. 1 a–c. In this case, the laser used was a YDFLP-200-M8-S-W-V2 from JPT Laser, and the glass was 4 mm thick ordinary white glass.

At the beginning of this test, we moved the laser beam to focus 1–2 mm below the underside of the glass. As the 2.5D galvanometer moved upward, the laser beam touched with the glass. The contacted glass was vaporized into fine powder and fell from the bottom, eventually shaping the circle-hole at the bottom along with the chipping edge appearance. As shown in Fig. 1c, the chipping edge on the lower surface is only 136 μm , which indicates better processing because the normal chipping edge is kept to within 150 μm .

There are many factors that affect the chipping edge on the upper surface of the glass, such as the material, heat accumulation, and the process parameters. In order to choose the appropriate pulse width to get a better chipping edge, let us see the different chipping edges of the glass upper surface with four different pulse widths: 9 ns, 12 ns, 14 ns, and 20 ns, which are shown in Figs. 2a–d. It can be concluded that the 12 ns pulse width results in the smallest chipping edge under the same power. At this setting, the laser has a single-pulse

energy of 0.95 mJ and a repetition frequency of 160 kHz with an edge chipping value of 291 μm .

Laser sanding treatment

When sanding glass to give it a blurry effect, it becomes translucent but opaque, protecting privacy, and enhancing aesthetics. It has a wide range of applications, such as in offices, or bathrooms. Currently, there are four main methods of manufacturing frosted glass: mechanical grinding, sandblasting, UV curing, and chemical treatment such as hydrofluoric acid etching, which all have the advantage of being widely applicable, but are complex and not environmentally friendly. However, laser-sanding treatment is more efficient, environmentally friendly, and cost-effective.

Mirrored glass is made by coating a reflective film on ordinary flat glass. Mirrored glass can be further processed with the help of laser processing technology. The appearance of mirrored glass after laser-sanding treatment is shown in Fig. 3a, showing

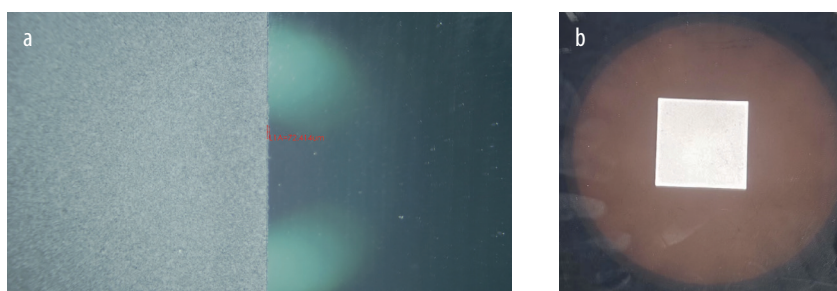


Fig. 3 (a) Sanding treatment, (b) treatment with frosted surface transparency

Company

Shenzhen JPT Opto-Electronics

Registered in 2006, JPT concentrates on the R&D, production, sales, and technology service of optical fiber devices, lasers and laser intelligent equipment. Based on laser technology, JPT integrates leading technologies such as laser and optics, test and measurement, motion control and automation, and machine vision. The company has highly valued intellectual property and has applied for more than 700 patents. JPT ranks top of MOPA pulsed fiber lasers globally, and in the top three of fiber laser manufacturers in China.

www.jptoe.com

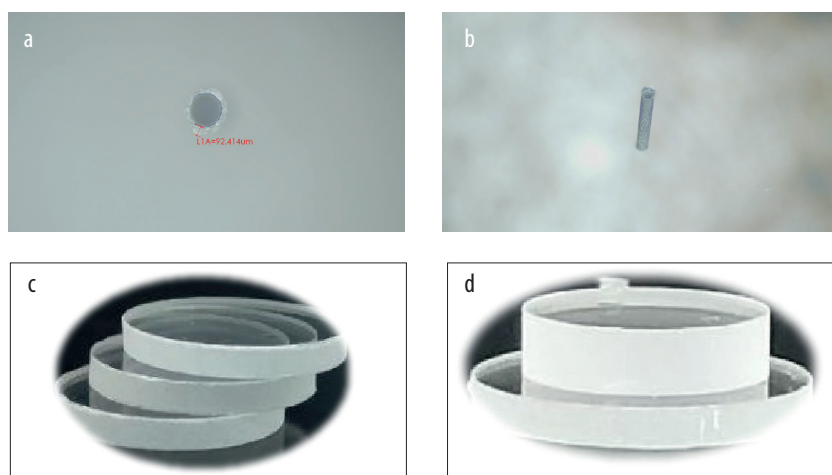


Fig. 4 (a) Chipping edge with 0.5 mm diameter, (b) side of the drilled hole, (c) hole with 5 mm thickness, (d) hole with 10 mm thickness

its fine texture and straight edges. It presents a composite effect of frosted surface transparency and mirror reflection when combined with lighting as shown in Fig. 3b.

Advantage of laser processing

The major advantage of laser processing is its ability to meet some complex requirements of glass manufacturing, such as manufacturing ultrathick glass materials, drilling micro holes, or following an irregular shape of the glass. Drilling a 5 mm thick ordinary white glass with a 0.5 mm diameter hole is shown as Fig. 4a. It can be observed that the chipping edge is only 92 μm (within 100 μm), and the side of the drilled hole is straight and without any taper, as shown in Fig. 4b.

Lasers can drill glass with thicknesses of up to 20 mm and diameters ranging from 0.3 to 150 mm. Fig. 4c and 4d show the drilling results for glasses with thicknesses of 5 and 10 mm, respectively. The overall chipping edge kept within 300 μm is considered to be at a good level. The specific processing efficiency is shown in Table 1.

When processing irregular-shape holes, lasers can achieve polygonal glass drilling by adjusting the software design as shown in the image on p. 28. There are many applications using this processing method, such as phone glass covers in consumer electronics, the glass panels of automotive displays, and glass products in daily life such as spectacles and watches. In the photovoltaics (PV) industry, holes must be drilled in the backplane of PV glass to bring the electrical conductors of the photovoltaic cell modules out to the junction box. Laser glass drilling has become the method of choice due to its high efficiency, environmentally friendliness and easy automation integration.

Conclusion

Based on the specific requirements of laser processing, the M8 series of nanosecond pulse, infrared fiber lasers developed by JPT has shown excellent performance in glass drilling and glass sanding processes by achieving higher single-pulse energy and a larger peak power. JPT's M8 series lasers adopt

the master oscillator power amplifier (MOPA) structure, where the master oscillator utilizes a semiconductor laser as the seed source, and power amplification is achieved through a wave fiber amplifier. Since its introduction in 2021, the series has undergone multiple iterations, upgrades, and optimizations to develop lasers with various power levels for different applications. The medium-low power lasers, such as 20 W and 50 W, are suitable for surface treatment and the etching of heat-sensitive materials. The medium-high power lasers, ranging from 100 W to 300 W, exhibit excellent performance in applications such as glass drilling, deep engraving, and glass sanding processes.

Keeping the independently adjustable pulse frequency feature of M7 series lasers, the M8 series lasers have undergone significant optimizations in pulse peak power and laser beam quality. This series maintains excellent beam quality even under high-power working conditions, with a peak power of up to 300 kW as shown in Table 2 and Fig. 5.

The JPT M8 series lasers, with their higher single pulse energy and

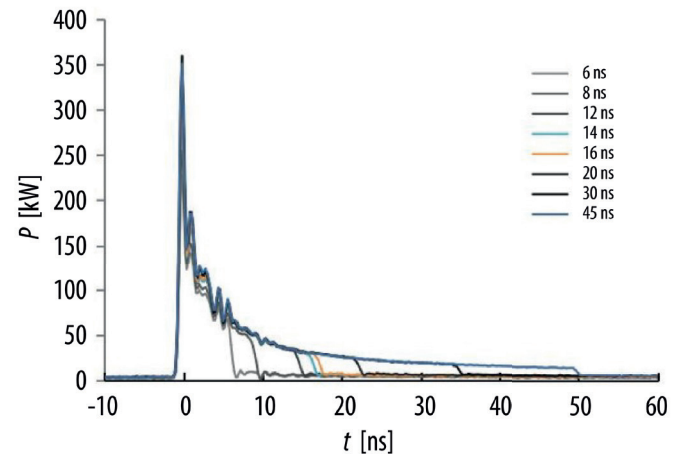


▲ JPT M8 series laser

► **Table 1** Different thickness glass/drilling diameter/drilling time

Drilling diameter [mm]	Glass thickness [mm]	Drilling time [s]		
		2	5	10
0.3		0.8	1.1	3.4
10		1.0	1.6	3.3
20		1.8	2.4	6.7
30		2.8	4.8	11.5
40		4.7	6.8	15.9
50		5.5	8.6	20.0
60		9.1	13.3	23.0
70		14	16.0	29.0
80		17	27.0	40.0
100		24	43.0	81.0
120		47	80.0	/
150		63	/	/

Optical Properties		
Parameter	Specification	Remark
M^2	<1.5	
Nominal average output power [W]	>200	
Pulse energy [mJ]	0.95 mJ @ 12 ns	
Pulse duration [ns]	6 – 200	adjustable
Peak power [kW]	10 – 350	
Repeat frequency [kHz]	1 – 4,000	adjustable
Output power instability [%]	<5	
Central emission wavelength [nm]	1064	
Output beam diameter [mm]	3 ± 0.5 or 11 ± 1	1/e ²
Output power tuning range [%]	0 – 100	
Emission bandwidth @ 3dB [nm]	<20	3 dB linewidth
Polarization orientation	random	

Table 2 Performance index**Fig. 5** Peak power curve, waveforms 6 ns to 45 ns

greater peak power, have shown excellent performance in glass drilling and glass sanding applications, which

brings efficient processing methods to industrial automation, and which is expected to become an important

tool for laser processing in the glass industry.

DOI: 10.1002/phvs.202400031

Authors

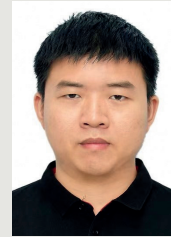
Mason Zhang, the senior manager in the laser application technology department of Shenzhen JPT Opto-electronics, has more than ten years of experience in MOPA fiber lasers and DPSS laser applications. He is currently responsible for the laser application development and market development of laser products.



Yaron He, the supervisor in the laser application technology department of Shenzhen JPT Opto-electronics, has been engaged in laser application technology for nearly ten years. Relying on his rich work experience, he helps customers from different industries with all types of application problems, and has won a good reputation.



Hanan Huang is the engineer in the laser application technology department of Shenzhen JPT Opto-electronics. Hanan obtained his bachelor's degree from Chongqing University in China, and now he is in charge of the laser applications of fiber optics, solid-state lasers, and laser applications in glass.



Shenzhen JPT Opto-electronics Co., Ltd., 1-12F Build A, Kemron Science Park, Guanlan Hi-tech Industrial Area, Longhua, Shenzhen, China 518110; e-mail: sales@jptoe.com, www.jptoe.com

Rock Solid

Zero offset frequency combs

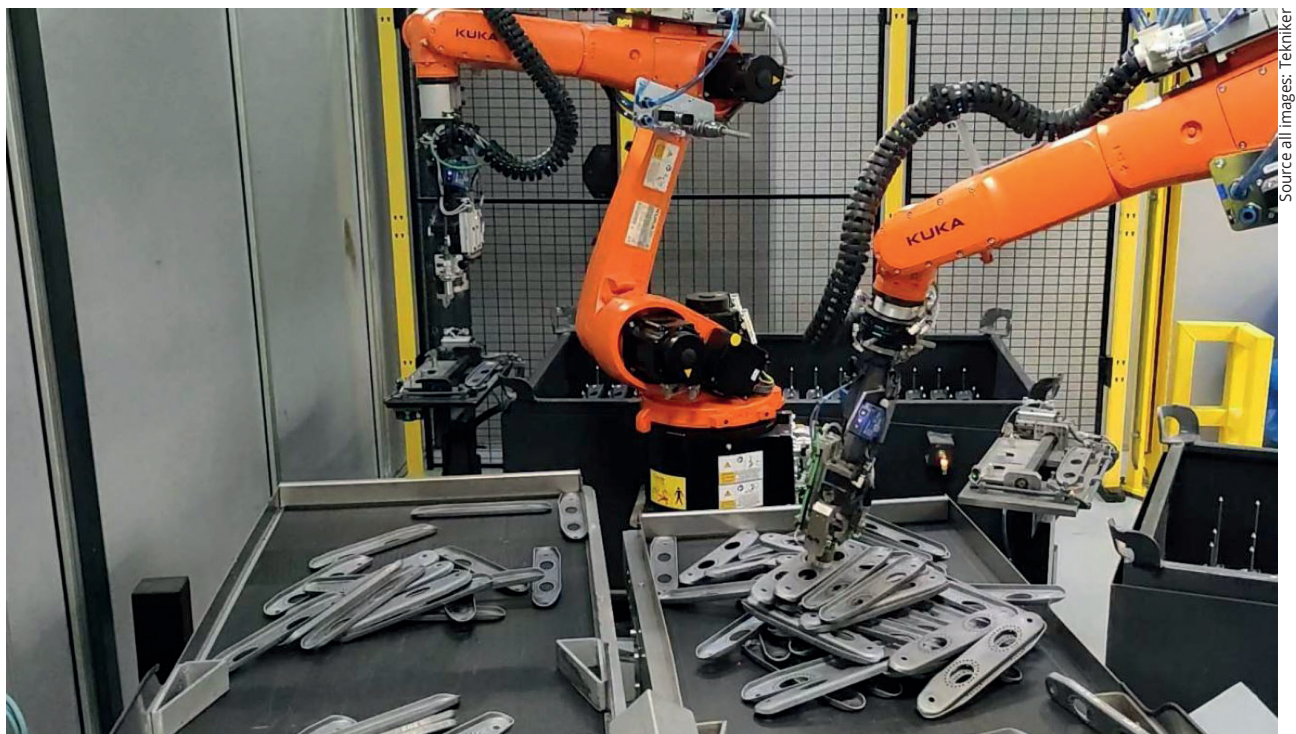


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3D vision helps to precisely palletize parts

Reliable part recognition allows the entire workflow to be optimized and automated, which speeds up palletizing, saves costs, and relieves employees



Source all images: Tekniker

The Spanish robotics specialist Tekniker has developed a solution that allows chaotically lying parts to be automatically gripped from containers and placed in other containers in an orderly manner. The integrated MVTec Halcon 3D vision software ensures precise gripping of those parts.

Fully automated part picking by robots is a major technical challenge. A particular difficulty is that the components are not always delivered to the robot in an orderly fashion, but unsorted and even overlapping each other. This means that humans still frequently have to intervene. The Spanish company Tekniker has developed an application based on machine vision that enables fully automated bin-picking with two robots. A particular highlight is the 'surface-based matching' 3D vision technology that reliably recognizes the delivered components, i.e., acts as the eye of the robots and enables precise gripping.

Tekniker, based in Eibar in northern Spain, specializes in the devel-

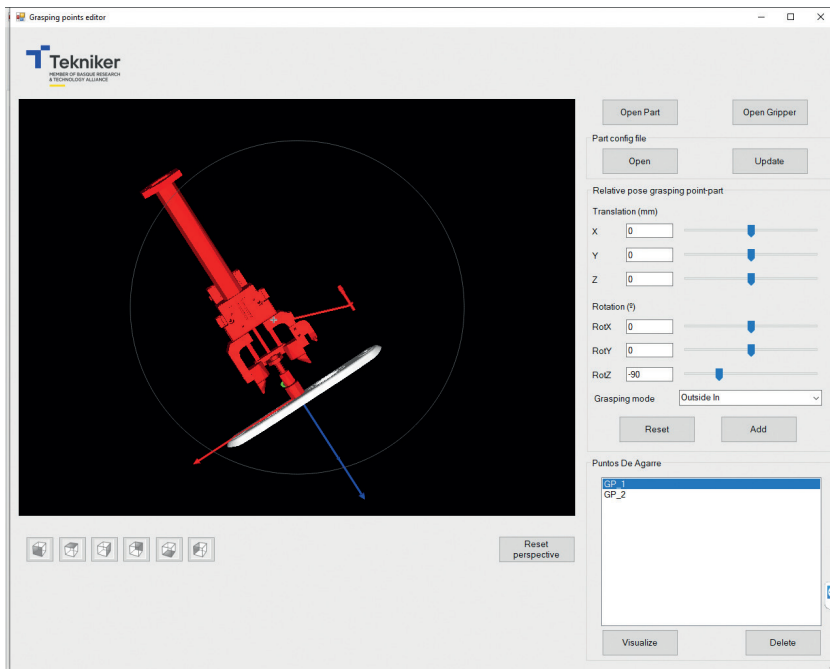
opment of technology solutions for automation, industrial robotics, and sensor technology, among others. The company serves a wide range of industries such as aerospace, automotive, or machinery and plant engineering. One of Tekniker's customers is the Cikautxo group, a Spanish manufacturer of vibration-damping and fluid-conducting components for the automotive industry. On behalf of the company, Tekniker's team of experts has developed a machine vision-controlled robot system for the automated palletizing of components for industrial production. Robots remove components that are lying randomly in a box and then place them in an orderly manner into a container

▲ The machine vision solution enables two robots to pick up the components in parallel

that is specially adapted to the geometric features of the parts. They are then ready for further processing in the production workflow.

Relieve employees through process automation

"Until now, the palletizing of parts was carried out purely manually. Our goal was to automate this process end-to-end in order to speed it up, increase productivity, and save costs. In addition, our workers were to be relieved of monot-



The editor, included in the Tekniker software, makes it easy to define where the component is to be gripped by the robot.

onous, ergonomically unsound tasks so that they could devote themselves to more demanding tasks,” explains Kepa Laka, automation and robotics area manager at Cikautxo. One option to implement process automation was a mechatronic system. However, this approach offers a low level of flexibility and reliability and, on top of that, generates a lot of noise. Therefore, Tekniker decided to use a solution based on machine vision.

The system setup consists of two industrial robots from Kuka, a 3D scanner from Photoneo, a depth camera from Intel, a PC running the machine vision software, and a Simatic PLC from Siemens to control the cell. In the process, one of the robots first removes the stamped parts in large quantities from the input bin using a magnetic multifunction gripper and deposits them on two conveyor belts. The removal is

stopped as soon as a certain volume of parts is reached on both belts. This is calculated using data provided by the depth camera as well as a customized Halcon algorithm that combines 2D and 3D vision tools. The machine vision software on the PC also continuously processes the data from the 3D scanner and provides the robots with the position and orientation of the parts best suited for gripping on the conveyor belt.

With this data, the second robot already begins to pick up the parts from the conveyor belts and – also with the help of 3D vision – aligns them so that it can sort them into two target bins in an orderly manner. After the first robot stops picking from the input bin, it ‘helps’ the second: it also picks up parts from the conveyor belt, aligns them and sorts them into the target container. Incidentally, this works at a speed of eight seconds per part. During this

process, the parts must be inserted into guide bars within the target container with the front facing upwards and with a tolerance of 0.5 millimeters. Should the gripped part face downwards, it is first placed in a rotating device to pick it up again in the correct position.

Precise localization of disordered parts

The particular challenge in this setup is that the robots need to recognize the position and orientation of components in 3D space precisely in order to pick them up and put them down again safely. “We developed the Smartpicking software to meet this requirement and integrated it into the overall solution. The software is able to identify objects accurately by analyzing 3D data and using the surface model as well as the corresponding geometric information. At the heart of the Smartpicking

Companies

MVTec Software

Being a leading international manufacturer of software for machine vision, MVTec’s products are used in all demanding areas of imaging, and enable new automation solutions for the Industrial Internet of Things by providing high-end technology such as 3D vision, deep learning, and embedded vision. Machine vision software from MVTec is developed and designed at the headquarters in Munich, Germany.

www.mvtec.com

Tekniker

The non-profit-making Tekniker foundation is a Basque technology center specialized in advanced manufacturing, surface engineering, product engineering and ICTs for manufacturing. Its mission is focused on bringing about growth and wellbeing for society through R&D&I actions and by furthering the competitiveness of our industrial fabric in a sustainable manner.

www.tekniker.es

Cikautxo

As part of the Mondragon Corporation, Cikautxo specializes in the development and production of rubber and plastic components for a variety of different applications. Since its establishment, it has developed innovative, cutting-edge manufacturing processes to obtain a high level of efficiency and quality in the production of polymer parts. More than 3,000 employees in eight countries generate a turnover of 315 million euros.

www.cikautxo.es



Robots pick components from a box at the Cikautxo company that are lying in a disorderly fashion and then place them in a specific alignment.

solution is the machine vision software MVTec Halcon. It provides sophisticated algorithms and tools to precisely locate the parts lying chaotically on the conveyor belt and transmit the coordinates of the pick point to the robots,” explains Jorge Molina, a researcher in the smart and autonomous systems department at Tekniker.

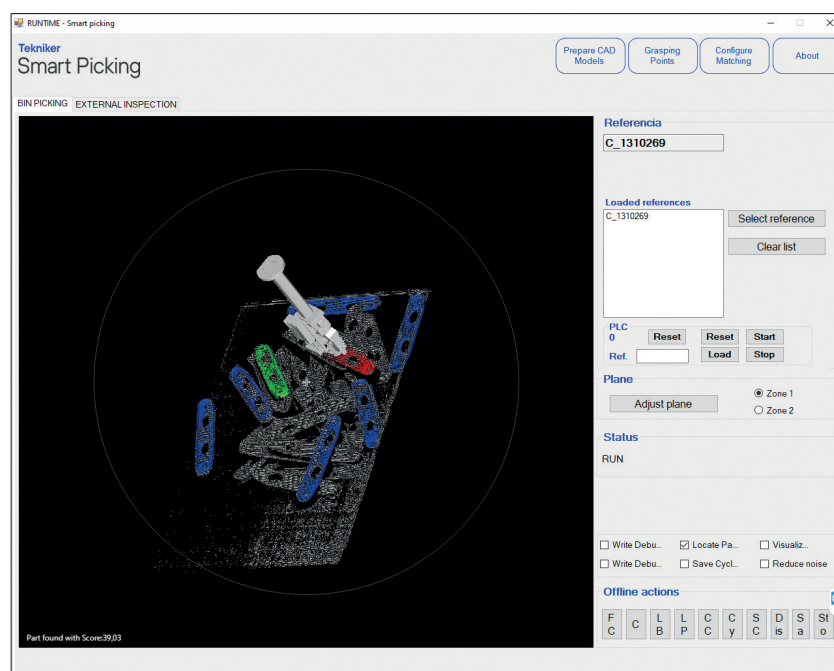
In concrete terms, classic 3D-based image processing methods are used. First and foremost, these include the ‘surface-based matching’ feature of Halcon. The technology uses data from 3D point clouds captured by the 3D scanner. The data is further processed using different filters and preprocessing oper-

ators to improve the position estimation of the parts. This enables very accurate positioning of objects – regardless of the nature of their surface. Now, the robots can recognize the parts and their exact position and can grip them without error. This works for a wide range of different parts as they occur in industrial production processes. Reliable position determination is ensured even for deformed or smooth surfaces without distinctive edges, which do not show any significant gray value differences in conventional images. To ensure a safe gripping process, the robots must also be able to exactly determine the relative position of the 3D camera in

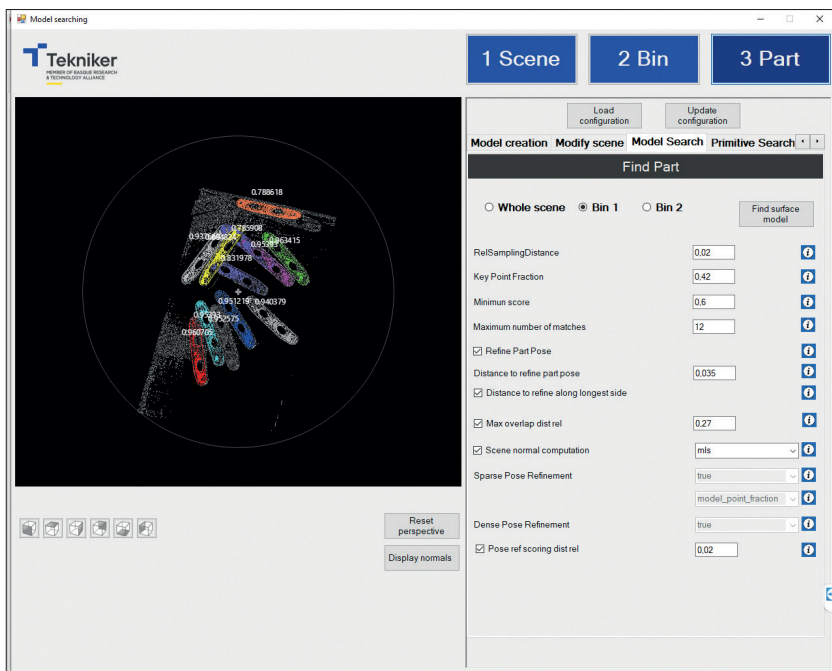
relation to the respective object in their coordinate system. To do this, a so-called hand-eye calibration is performed with the help of MVTec Halcon, e.g., with an associated calibration plate. This calibration is essential to establish the relationship between camera, robot, and the parts to be gripped. Only then does the robot ‘know’ exactly where its gripper is in relation to the object to be gripped, i.e., where it must move it in order not to grasp at nothing.

Avoiding collisions during the pick-and-place process

In addition to detecting and determining the position of the parts to be gripped, possible collisions between the robot arms and individual objects (components, containers, etc.) must be avoided during the entire pick-and-place workflow. This is where the ‘3D object processing’ technology integrated in Halcon comes in that makes it possible to determine which parts lie favorably on the conveyor belt and can initially be gripped without a collision. Based on this initial selection, the software then determines the optimal can-



The point cloud in the machine vision software shows the various components found (in blue), the best component to be gripped (in red) and the second-best component to be gripped (in green). The robot's gripper is shown in white.



The components can be found using different parameters within the machine vision software. The different colors indicate the score with which they were found.

didate using various decision criteria such as the height and orientation of the parts or the position of the gripping point, and returns the coordinates of its position to the robot. The robot can then safely carry out the next gripping process. The controlled sequence allows components to be removed in such a way that collisions and consequent disruptions to the workflow are reliably prevented. The software also detects the remaining capacity of the target container according to its volume calculated by the operators. A previously defined threshold value can then be used to determine whether further parts can be added to the container.

Increase process speed by up to 100 %

“Thanks to the robust machine vision capabilities in MVTec Halcon, we can automate and optimize the robotic palletizing process end-to-end. The software offers a large number of sophisticated machine vision tools that can be used to locate the parts to be picked up precisely, which ensures safe and smooth pick-and-place processes. We can also categorically exclude collisions of the gripper arms and ensure the safety and continuity of automated palletizing,” Jorge Molina sums up. “As a result of using the system, we have been able to increase process speed by up to one hundred percent, improve productivity accordingly, and on top of that, relieve our employees of routine tasks,” confirms Kepa Laka.

Fundación Tekniker

Jorge Molina
researcher
smart and autonomous systems dept.
Parke Teknologikoa, C/ Iñaki Goenaga, 5
20600 Eibar, Gipuzkoa – Spain
phone: +34 943 20 67 44
e-mail: info@tekniker.es
Web: www.tekniker.es

Cikautxo Group

Kepa Laka
automation and robotics area manager
Magdalena Auzoa, 2-B
48710 Berriatua, Bizkaia – Spain
phone: +34 946 133 000
e-mail: cikautxo@cikautxo.com
Web: www.cikautxo.es

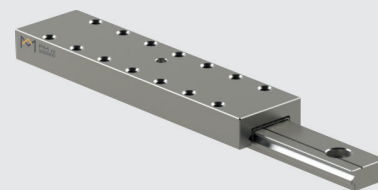
MVTec Software GmbH

Jan Gärtner
Product Manager HALCON
Arnulfstraße 205
80634 Munich, Germany
phone: +49 89 457-695-0
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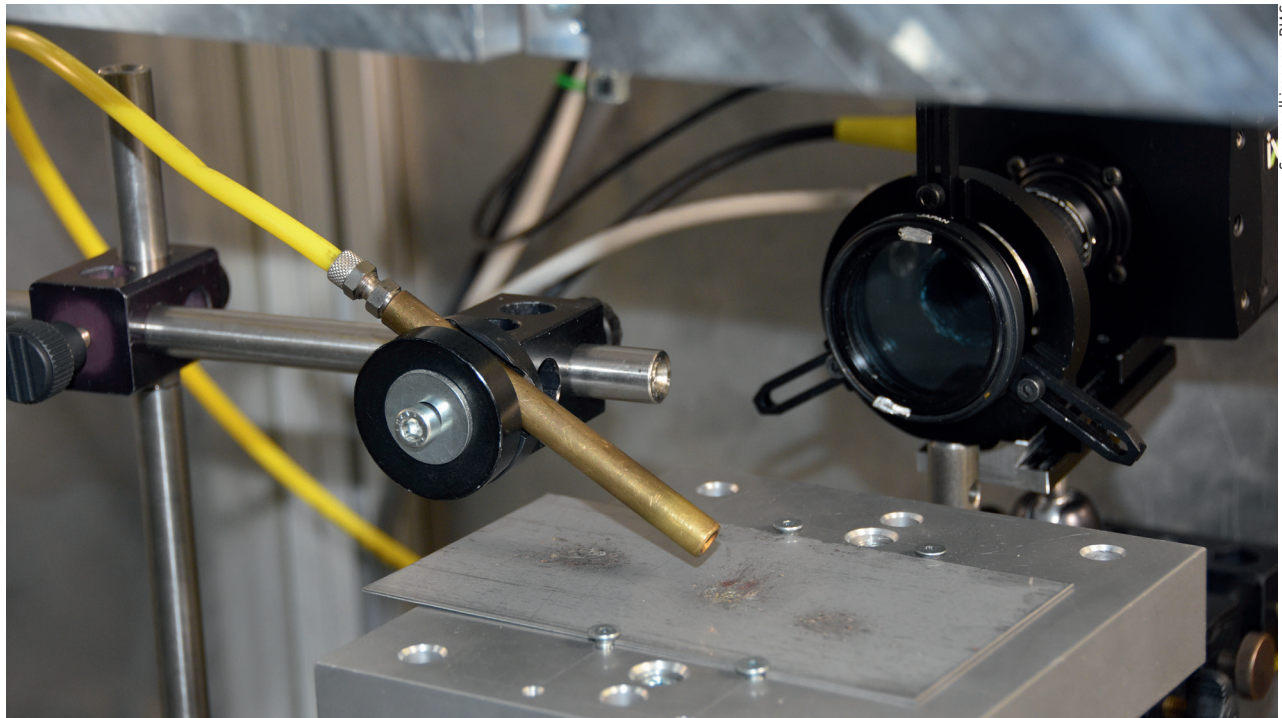
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Laser cleaning of insect residue without surface alteration

A pulsed CO₂ laser provides an effective shockwave-based cleaning process

Lewin Rathmann & Tim Radel



Source all images: BIAS

Insect residues disturb and interrupt the laminar air flow on airplane wings after a while. These residues therefore need to be repeatedly removed. Shockwave-based laser cleaning of insect residue on stainless steel (1.4544.9) is presented as a possible method to reduce insect residues in a single pass and without influencing the base material, as confocal laser-scanning microscope images demonstrate.

Climate change is one of the greatest social and ecological challenges that we face in the 21st century [1] and air traffic is identified as a major contribu-

tor accountable for 5 % of global greenhouse gas emissions [2]. This is due to the fuel consumption of commercial airlines that amounted to 360 billion liters

in 2019 [3]. Several solutions have been studied and brought into use to reduce this consumption. One of these is laminar flow technology on airplane wing surfaces that significantly reduces the drag and simultaneously increases airframe aerodynamic efficiency, thus reducing fuel consumption [4]. But this laminar air flow is disturbed by different factors, one being the accumulation of insect residue on the airplane wing that creates three dimensional disturbances. These surfaces must therefore repeatedly be cleaned to restore the initial smooth surface [4].

At this point, shockwave-based laser cleaning comes into play. There are three typical pulse laser cleaning methods: dry laser cleaning, liquid-assisted laser

Institute

BIAS – Bremer Institut für angewandte Strahltechnik GmbH

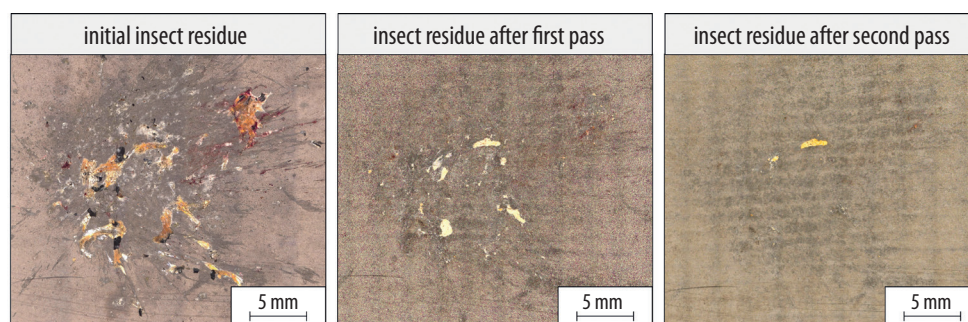
BIAS is a leading non-profit R&D performer in laser materials processing and optical metrology technologies, including:

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Fig. 1 Shockwave-based laser cleaning of insect residue adhered to 1.4544.9 in two passes (BIAS ID 240061)



cleaning, and laser shock wave cleaning. Dry laser cleaning can lead to significant heating or even removal of the base material in the micrometer range that is not tolerable. Furthermore, applying liquid-assisted laser cleaning would be challenging when cleaning downfacing wing surfaces [6] and the advantage over conventional cleaning with liquid media is negligible. This study therefore reports on the cleaning behavior of shockwave-based laser cleaning and its beneficial use to clean insect residue from a metallic aircraft surface.

Shockwave-based laser cleaning of insect residue was performed using a ML105E pulsed nanosecond TEA CO₂ laser from SCLR Lasertechnik. The beam was emitted with a wavelength of 10.6 μm over a full width half maximum pulse duration of 100 ns and at a frequency of 10 Hz. The beam had a rectangular shape and was guided by a concave focusing mirror onto the target's surface, which was made of 1.4544.9. The target was placed on an x-y table of type KT310-200 produced by Steinmeyer Mechatronik that performed the movement of the target to enable the areal cleaning process. The insect residue on the stainless steel 1.4544.9 was artificially created and consisted of a single flesh fly that was anesthetized and subsequently shot onto the steel's surface at a velocity of 70 – 90 m/s and an impact angle of 45°. The distance between the applicator and the sample was 30 cm. Afterwards, the residue was cleaned using a meander path, a pulse overlap of 33 % and a path overlap of 30 %. Prior to the first cleaning pass, the residue was imaged with an Olympus BX53M with a 2.5-fold lens by single images stitched together to provide an overview. Images were taken at 10-fold magnification for a more precise depiction of characteristic locations within the residue using a confocal laser-scanning microscope of type VK-X 3000 produced by Keyence. After the first and

second pass, the imaging was repeated to visualize the cleaning progress. The images were analyzed using the Multi-FileAnalyzer software, also provided by Keyence.

Fig. 2 on the left provides an overview of the insect residue on 1.4544.9. It can be seen that the residue is spread over an area of about 45 mm in width and 40 mm in length.

The distribution is not homogeneous, but concentrated in several locations, of which three are marked and depicted in Fig. 2 on the right as height images. The maximum peak

height S_p of the residue ranges on average between several 100 μm and 650 μm . Distinctive fragments of the exoskeleton, i.e., the insect shell, can be clearly seen as black dots in the residue. Organs and hemolymph are also observed.

Most of the initial adhered insect residue on the target was removed after the first cleaning pass, as Fig. 3 on the left depicts. The height images of the selected local residue distributions reveal that a reduction of their height of up to 88 % took place in the case of location 3, for example. There, the

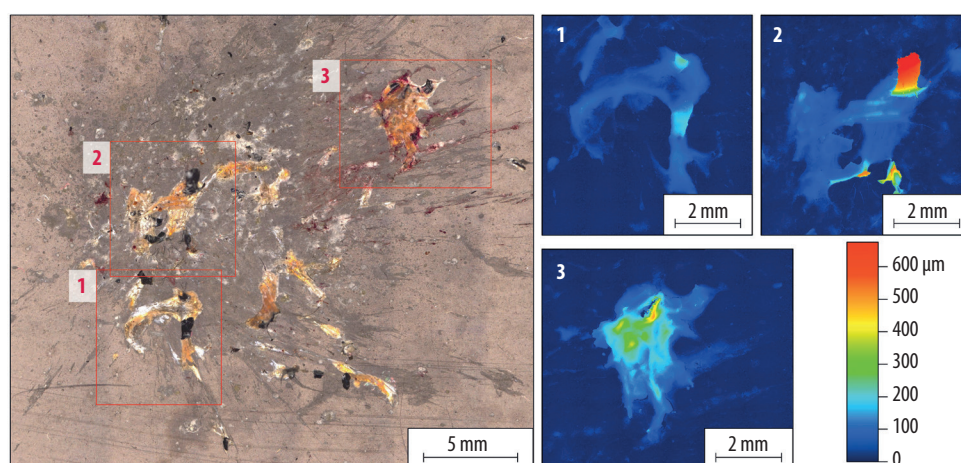


Fig. 2 Left: overview of initial insect residue on 1.4544.9. Right: height images of characteristic locations within the insect residue (BIAS ID 240062)

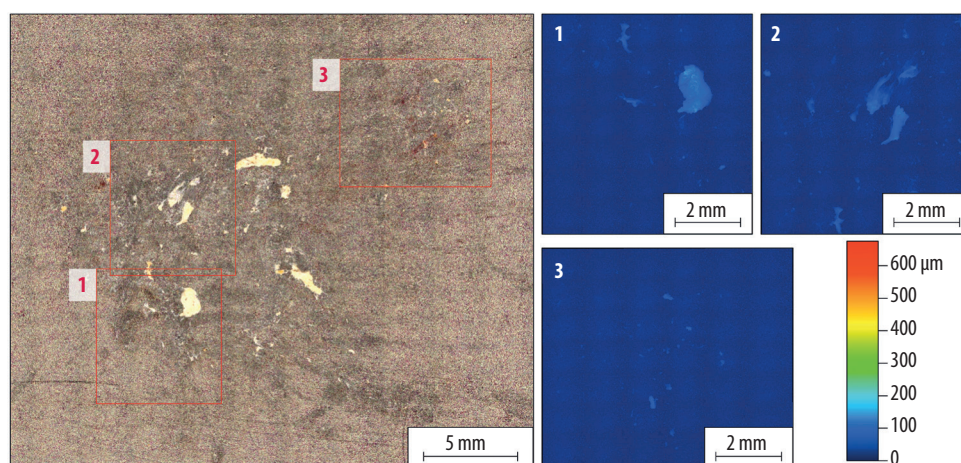


Fig. 3 Left: overview of insect residue on 1.4544.9 after the first cleaning pass. Right: height images of characteristic locations within the insect residue (BIAS ID 240063)

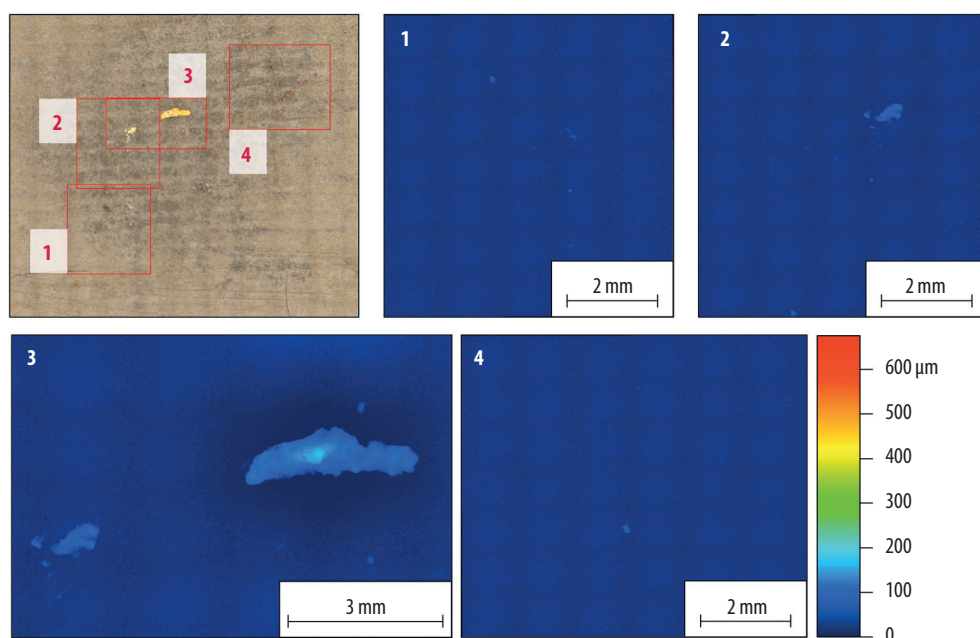


Fig. 4 Overview of insect residue on 1.4544.9 after the second cleaning pass and height images of characteristic locations within the insect residue. (BIAS ID 240064)

maximum peak height was decreased from 455 μm to less than 10 μm .

A second cleaning pass of the surface further reduced the volume of the insect residue, as Fig. 4 demonstrates. This reduction takes place in particular in areas 1 and 2. This is where S_p drops on average to 40 μm and 30 μm respectively, which corresponds to a reduction of 63 % and 74 %. Most of the remaining residue is in area 3. There, the residue still accumulates to a peak height of 160 μm , which can be further reduced in additional passes.

Fig. 5 depicts, on the one hand, the surface condition in an area at the edge of the target's surface that did not undergo any treatment, and on the other hand, the surface condition in an area that was cleaned twice. The comparison of both areas makes it clear that neither the surface texture nor the topography is influenced by the shockwave-based laser cleaning process after two cleaning passes.

The literature states that insect residue on airplane wings tested in a wind tunnel or on actual airplanes such as the Jetstar, DLC-9, Boeing 737, and Fokker F 28, if it reaches a critical height range of 100 μm to 400 μm [5], causes

boundary layer transition from laminar to turbulent flow. The insect residue S_p was 450 μm on average before the first cleaning pass and therefore above the range stated in the literature. The first cleaning pass already reduced that value to 165 μm on average, while a second pass did not change much on the average peak height but did reduce the volume of the residue. Nevertheless, a great and visible reduction of the residue can be observed when areas 1, 2, and 3 in Fig. 3 are compared to 1, 2, and 4 in Fig. 4. This reduction can be found in the decreasing overall average arithmetic height from 4.3 μm to 3.6 μm , which is a reduction of 15 %.

A fundamental factor as to whether a cleaning process can be used is the influence of the process on the base material. While in some cleaning cases an ablation of the surface within limits is tolerable, this does not apply to the wings of airplanes. Shockwave-based laser cleaning was used here to clean the insect residue off 1.4544.9. Besides its beneficial cleaning behavior, this study shows that although multiple passes were made to reduce the residues, no alteration of the surface within the cleaning area could be detected (Fig. 5).

The cleaning process affects neither the initial surface topography nor the structure of the surface. This is supported by comparing the mean arithmetic height and maximum height (Fig. 5).

This study reports on the cleaning behavior of shockwave-based laser cleaning and its beneficial application of cleaning insect residue from 1.4544.9. According to microscope images, the cleaning process shows a great cleaning effect after a first cleaning pass due to a significant reduction of the insect residue in volume and height, and with the potential to remove all of it after multiple passes. Furthermore, the base material shows no signs of removal or alteration. It is therefore concluded that shockwave-based laser cleaning using a TEA-CO₂ laser is generally technically suitable for such cleaning operations.

DOI: 10.1002/phvs.202400025

The Ultra Performance Wing project (UP Wing, project number: 101101974) is supported by the Clean Aviation Joint Undertaking and its members.

This research is co-funded by the European Union. Views and opinions are however those of the author(s) only and do not necessarily reflect those of the European Union or Clean Aviation

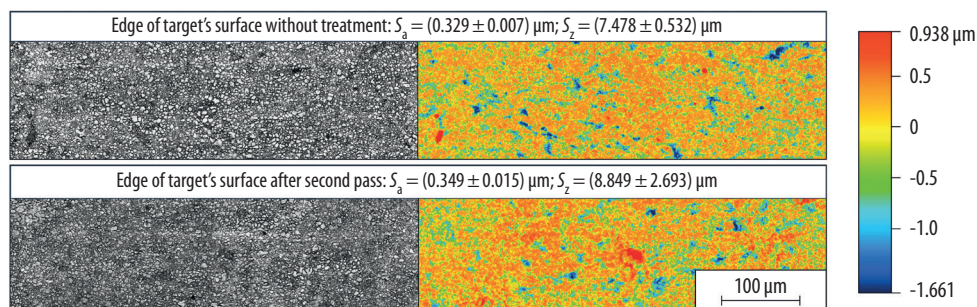


Fig. 5 Surface of 1.4544.9 at different positions. Above: the edge of the target's surface without treatment. Below: the middle of the target's surface after a second pass. Each row shows the laser intensity image on the left and the height image on the right. The scale applies to the row above accordingly. (BIAS ID 240065)

Joint Undertaking. Neither the European Union nor the granting authority can be held responsible for them.



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Authors

Tim Radel joined BIAS in 2014. In 2020, he took over responsibility as head of the laser processing department, expanding its scientific fields with a focus on surface structuring and laser polishing. The cleaning of metal surfaces using lasers completes the department's portfolio.



Dr.-Ing. Tim Radel, M.Sc. Lewin Rathmann, BIAS – Bremer Institut für angewandte Strahltechnik GmbH, Klagenfurter Str. 5, 28359 Bremen, Germany; phone: +49 421 218-58044, e-mail: rathmann@bias.de, Web: www.bias.de, www.bias.de

Lewin Rathmann studied mechanical engineering and became a research assistant at BIAS in 2018. During his career, he gained experience in various fields ranging from micro metal forming and process simulation to laser-based surface structuring using LIPSS to enhance tribological properties. Most recently, he studied the feasibility of using a pulsed CO₂ laser to remove contaminants from metal surfaces.



Additive Manufacturing

Preview – read the full article in PhotonicsViews issue 1/2025

The industrialization of additive manufacturing

Keynote addressing all aspects of industrialization of AM along the manufacturing route

Our world is constantly facing a wide variety of social challenges – currently, issues such as climate change, security, demographic change, and resource conservation are of significant importance and show an acute need for action. Among other things, disruptive technologies are needed to tackle such problems. Additive manufacturing (AM) is regarded as the ‘game changer/paradigm shift’ technology for the digital, automated production of the future – as the key enabler of ‘Production 2.0’. This sustainable and resilient technology enables new paths to innovative solutions across all industries through a high degree of individualization (mass customization) and great design freedom (‘manufacture for design’ instead of ‘design for manufacture’). For example, internally cooled turbine blades for H₂-capable gas turbines, lightweight structures for more efficient aircraft or patient-specific implants are only made possible by AM. In this way, AM

makes an important contribution to solving the social challenges mentioned above. Now it is necessary to transfer this technology to broad industrial use.

The industrialization of the technique requires an end-to-end approach along the AM route – from design to the finished part. Advances in process development, for instance, have led to process parameters for high-power lasers up to 1.5 kW in laser powder bed fusion (LPBF). The integration and use of dynamic ring mode lasers in particular has brought an increase in productivity of up to 200 % and leads to a significant cost reduction. The development of systems for the detection and minimization of process by-products such as spatter and fumes and for in-situ monitoring of any defects ensure high quality in an industrial production environment. When industrializing AM, it is also necessary to merge the virtual and physical worlds through digital twins, enabling

quality control and automated feedback into CAD/CAM processes. As part of the collaborative BigDataLMD project, Fraunhofer IAPT has developed a data infrastructure that captures machine and process data using in-situ monitoring, generating actionable insights to improve the stability of the powder laser directed energy deposition (DED) process.

AM can be successfully industrialized by ensuring a holistic and consistent transfer of the individual advances along the manufacturing route.

Fraunhofer IAPT

Prof. Dr.-Ing. Ingomar Kelbassa
Am Schleusengraben 14
21029 Hamburg
Germany
phone: +49 40 484010-500
ingomar.kelbassa@iapt.fraunhofer.de
Web: www.iapt.fraunhofer.de

Integration of sensors during laser powder bed fusion

Design criteria for a solid connection of AM components with RFID tags

Andy Schönherr, Sven Voigt, Bernd Schob, Julia Ruiz Bucksch, and Lothar Kroll



Laser powder bed fusion (PBF-LB/M) is an additive manufacturing (AM) process to produce high-strength, functionally integrated, lightweight metal components which cannot be built conventionally. This article addresses the expansion of functionality by integrating sensors within closed cavities. For this reason, the building process was stopped just before the cavities were closed. After positioning the sensors, the building process was continued and a solid connection to the AM component was established.

Aerospace aluminum alloy for additive manufacturing

Reduction of the mass of components in the aerospace industry has a significant impact on fuel consumption. The PBF-LB/M process is an ideal process for manufacturing topology-optimized lightweight structures. Metal powder is applied in layers on a powder bed and fused using a laser. The ability to produce overhangs permits the production of components with hollow structures like fluid channels, for example. The building process can be interrupted to integrate other media into manufactured cavities. For this, metal powder

must be removed from the inner cavity before inserting the media. The greatest risks in this case are the process heat, powder contamination and exposure to the laser beam. This paper deals with the integration of sensors in PBF-LB/M components with the aim of safe signal transmission to the outside. In addition, the design of criteria for safe positioning as well as the nondestructive and fixed connection of the sensors inside the cavity are examined.

The aluminum alloy AlSi10Mg was chosen for the sensor integration. As an authorized aerospace alloy, it meets high requirements in strength and durabil-

▲ **Fig. 1** Additive manufactured aluminum components with integrated sensors: (left) cutaway component, (right) complete component (Source all images: TU Chemnitz)

ity with relatively low thermal demands during processing and posttreatment. The particle size of the powder was determined using a particle analyzer and was between 20 and 63 μm . First, cube-shaped test specimens were additively manufactured with different process parameters on the SLM 250 HL from Nikon SLM Solutions. A stable process window was defined for the alloy for a layer thickness of the applied powder

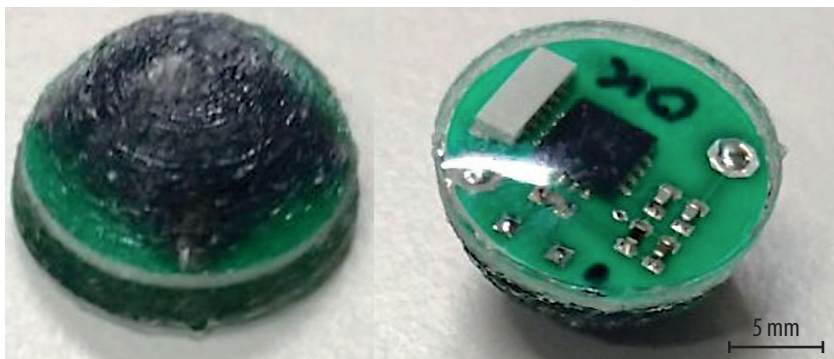


Fig. 2 RFID tag molded in epoxy resin

of 50 μm . With a scanning speed of 930 mm/s, a laser power of 350 W and a hatching distance of 150 μm , test specimens with material densities of approx. 99.7 % could be generated. Microscopic examinations of micrographs were carried out using a Keyence VHX 600 light microscope. Tensile tests with seven additively manufactured cylindrical specimens were tested in accordance with DIN 50125-B and tested in a Zwick Z100 tensile testing machine. Tensile strengths of approx. 460 MPa were measured.

Characterization of RFID sensors

A radio frequency identification (RFID) tag was selected for integration into the additively manufactured components. A major benefit of this type of technology is its ability to transfer signals wirelessly, even though the tags do not have their own energy storage. The tags get the energy necessary for data transmission from an RFID reader that generates an electromagnetic field. RFID tags are used in a variety of applications, for example to identify products, monitor production processes, or record operating hours. The integration of RFID tags in PBF-LB/M components was investigated by Pille et al. [1] and Sehr

et al. [2]. Data transmission through thin-walled component structures was demonstrated, although no information on specific transmission frequencies was published. For this work, an RFID transceiver was used that operates in the low-frequency range at 134.2 kHz. Together with a microcontroller and an acceleration sensor, it was mounted on a temperature-resistant, round circuit board with a diameter of around twenty millimeters using high-temperature solder. The sensors were encapsulated in epoxy resin to protect them from metal dust during the AM process. Fig. 2 shows a molded sensor.

The RFID tags were analyzed using the ZVR vector network analyzer from Rohde & Schwarz and the MRD2EVM RFID reader from Texas Instruments. In an initial test, the transmission power of the sensors was measured out of closed aluminum cubes with different wall thicknesses. After inserting the sensors into the additively manufactured cube made of AlSi10Mg, it was closed with a lid and any possible leakage holes were insulated. The tests showed that no radio connection could be established from the enclosed cubes at the selected frequency.

As signal transmission with the developed RFID tag was not possible

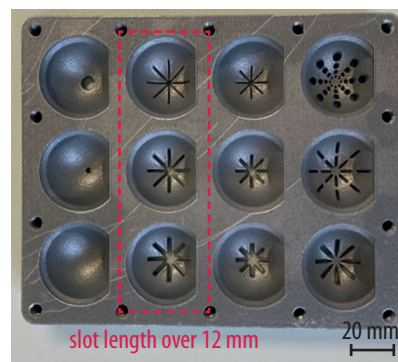


Fig. 3 Additive manufactured cavities with varied star-shaped slot geometries to investigate RFID communication

through closed component walls, transmission tests were carried out using different small hole geometries. An aluminum plate with twelve additively manufactured cavities was produced, each of which had holes or star-shaped slots with different dimensions that lead to the outside (Fig. 3). The cavities were equipped with RFID sensors and then closed and isolated with an aluminum plate. The experiments showed that stable communication of the RFID tags was only possible through the star-shaped slots with a minimum slot length of 12 mm. The maximum range of the RFID tags around the AM components was 10 mm.

Sensor integration during the AM process

During the closing of the cavities in the PBF-LB/M process, the internal sensors are exposed to thermal forces caused by process heat, hot molten spatter and the direct influence of the laser beam. Temperatures of 40 – 60 °C exist in the area above the powder bed, which the epoxy resin used to cast the sensors can withstand without any problems. To investigate the effects of the laser beam on the potting compound, cube-shaped cavities with internal dimensions of $20 \times 20 \times 2 \text{ mm}^3$ were addi-

Institutes

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The Institute of Lightweight Structures and Polymer Technology has many years of extensive expertise in powder-based additive manufacturing. Its work focuses on the development of design guidelines and design criteria for processing demanding materials such as

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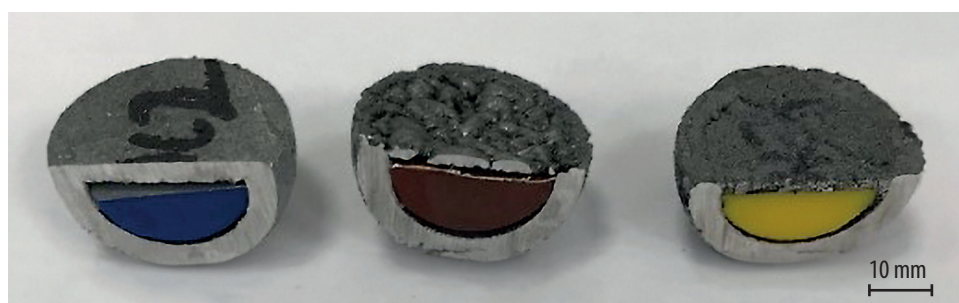


Fig. 4 Cut samples with glued sensor dummies: (left) aluminum adhesive tape, (center) copper adhesive tape, (right) aluminum-bitumen-tar adhesive tape

tively manufactured. The building process was interrupted before the cavities were completely closed. After removing the aluminum powder from the cavities, they were filled with epoxy resin, then a layer of powder was applied on top and the build process continued. However, the resin was destroyed during exposure to the laser. The resulting plasma column was so intense that the build process had to be stopped after only three layers. These results show that molded sensors cannot simply be exposed further without additional protection. It is therefore essential to integrate a type of heat shield to protect the sensors from the direct effects of the laser.

In the next step, the safety effect of various metal adhesive tapes was analyzed. For this study, semicircular sensor dummies made of epoxy resin were covered with aluminum-bitumen-tar adhesive tape (1.7 mm thick), copper adhesive tape (0.2 mm thick) or aluminum adhesive tape (0.2 mm thick) and inserted into additively manufactured cavities in the PBF-LB/M machine. There was a height difference of about one millimeter between the adhesive tapes and the lid of the cavity. The hollows that were left were filled with powder. The build process was then continued and the cavities were closed with horizontal 0° layers. The epoxy resin casting was not damaged by the laser in

any of the tests. No solid downskin layer could be built over the copper adhesive tape, while the aluminum-bitumen-tar adhesive tape was badly damaged by the laser. A solid top layer was only produced over the undamaged aluminum adhesive tape, but unmelted powder remained between the adhesive tape and the top layer. The cut samples from the tests with the metal adhesive tapes are shown in Fig. 4.

Binder et al. used aluminum plates as heat shields over sensors to protect them from the laser beam [3]. Based on this knowledge, the integration of aluminum plates into the PBF-LB/M process to protect the RFID tags was tested in this work. For this test, round plates with a diameter of 24 mm and 1 mm thick were inserted into specially manufactured cavities. These were designed in a way that a hollow space was formed underneath the plates. Powder was placed over the plates and then exposed with a parameter set for a layer thickness of 90 μm . The increased layer thickness reduces the energy input from the laser, as the building process proceeds more quickly upwards. A complete solid connection between the plates and the AM component was produced in the area above the aluminum plates. The remelting depth on the top of the plates was around 0.6 mm and the material density in this area was around 99.75 %. These bulged slightly downwards in the cavity under the plates due to the stresses created during the energy input. Afterwards, hemispherical encapsulated RFID tags were bonded with the same aluminum plates on a flat surface and inserted into cavities provided for this purpose in the AM machine. The plates partially bulged upwards during the lighting process, which resulted in a collision with the machine's powder recoater, and the building process was stopped. To solve this problem, thin outer rings were initially additively manufactured over the inserted sensors in place of closed cover layers. This made it possible to gener-

ate continuous connections between the plate edges and the cavities without any excessive bulging. After building up three layers of the rings, the surfaces above the sensors were completely exposed and the cavities were closed. The powder over the plates was completely remelted and solid connections between the sensors and the cavities were created. This procedure enabled the safe completion of the building process. A cut test specimen is shown in Fig. 5. After the successful sensor integration, signal transmission tests demonstrated that the RFID tags could communicate out of the test specimens through the slots designed for this purpose.

In some trials, the inserted sensor tags were twisted or pushed out of the cavity by the powder recoater during the powder coating processes. To prevent this, the geometry of the molded sensors was modified to stop them from tilting or twisting. This was made possible by a combination of flat surfaces and bevels on the half-round shape of the mold. The final outer diameter of the sensors was 24 mm. The outer shape of the encapsulation also helps to ensure that the sensors align themselves correctly when they are inserted from a certain height.

In tests, sensor dummies with this optimized shape were held from a height of 10 mm above the corresponding cavities using a vacuum and then dropped. The sensors aligned themselves in the cavity up to a combined twist around the z-axis of up to 30° and a tilt of up to 20° . The final geometry of the sensor is shown in Fig. 6.

Outlook

The safe and non-destructive integration of RFID tags into PBF-LB/M-manufactured components significantly expands the functional diversity of AM components made of metal. In addition to the conventional tasks of RFID tags, such as the saving of part data, equipping them with different

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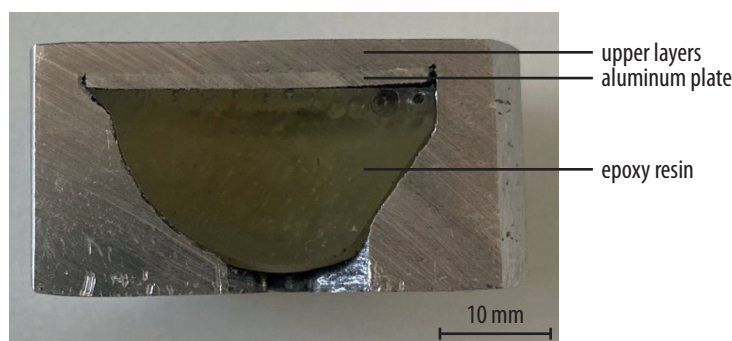


Fig. 5 Cut sample – solid connection of integrated sensor dummy in a closed cavity

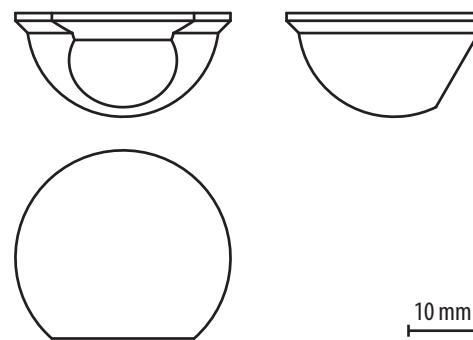


Fig. 6 Normal projection of the final sensor geometry

low-power sensors enables the recording of important characteristics such as temperature, the magnetic field, acceleration, or orientation. Communication and energy transfer through closed component walls remain a major challenge, so more research is needed on wireless signal transmission. A promising approach could be the solid connection of sensors to the component structure. The solid connection of sensors in components made of other metal alloys, such as titanium, should also be studied. Reliable, non-destructive integration must be made possible, particularly in materials that are difficult to handle and have high process temperatures. Innovative methods are needed to guarantee the longevity and functionality of the sensors under extreme conditions.

*

Our grateful thanks go to the Federal Ministry of Economic Affairs and Climate Protection (BMWK) for providing financial resources of the IFUNK research project (IFUNK – Process design and design concepts for in-situ-functionalized AM components) as part of the aviation research program (LuFo VI).

DOI: 10.1002/phvs.202400034

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Authors

Andy Schönherr

studied at the faculty of mechanical engineering at the University of Technology Chemnitz. After working for several years as a mechanical engineer in industry, he moved to the Institute of Lightweight Structures and Polymer Technology. In the research field of additive manufacturing, he is specialized in powder-based processes, with a focus on the construction and simulation of innovative components.



Andy Schönherr, University of Technology Chemnitz, Reichenhainer Str. 31/33, 09107 Chemnitz, Germany, phone: +49 371 5313-4265; e-mail: andy.schoenherr@mb.tu-chemnitz.de, www.leichtbau.tu-chemnitz.de/am/

Further authors

Sven Voigt, Fraunhofer Institute for Electronic Nano Systems, Chemnitz, Germany

Bernd Schob, University of Technology Chemnitz, Institute of Lightweight Structures and Polymer Technology, Chemnitz, Germany

Julia Ruiz Bucksch, Capgemini Engineering, Munich, Germany

Lothar Kroll, University of Technology Chemnitz, Institute of Lightweight Structures and Polymer Technology, Chemnitz, Germany



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Delivering $>100\ \mu\text{J}$ pulses at 1,980 nm with $<400\ \text{fs}$ duration and $>15\ \text{W}$ average power

Christian Gaida, Tobias Heuermann, Sven Breitkopf, Tino Eidam, and Jens Limpert



Source all images: AFS Jena

A novel compact laser utilizing thulium-based fiber chirped-pulse amplification (CPA) technology has been developed to enable essential tasks such as microwelding or the precision cutting of filaments with semiconductors such as silicon. At a central wavelength of 2 μm , the activeTwo-15 provides pulse energies exceeding 100 μJ and an average power output surpassing 15 W, and can be seamlessly integrated into systems for materials processing.

When it comes to cutting-edge ultrafast laser applications such as silicon processing, longer laser wavelengths are often preferred over 1- μm lasers due to the transparency of semiconductors in this wavelength region. Consequently, there is a strong demand for ultrafast lasers with small footprints and wavelengths around 2 μm [1, 2, 3]. Thulium-based fiber lasers have shown promise in efficiently producing high average and peak-power directly in this wavelength region [4–8] without the need for any postconversion of the central wavelength as with optical parametric

amplifiers. This results in a simpler and more reliable laser architecture. Here we present an industrial-grade Tm-based fiber laser that emits $>100\ \mu\text{J}$ pulses at a 1,980 nm central wavelength with $<400\ \text{fs}$ pulse duration at a repetition rate of up to 150 kHz, corresponding to $>15\ \text{W}$ average power. The system allows important process parameters such as pulse energy, repetition rate and pulse duration to be adjusted and monitored. The laser is designed to operate without requiring vacuum equipment and still avoids water-vapor absorption in an elegant way, which allows

for nearly diffraction-limited beam quality and excellent pointing stability. It is engineered to be of industrial-grade reliability and optimized for long-term operation. Its packaging is perfectly suited for integration into larger machines, to be used for wafer post-processing for example.

System setup and output specifications

This laser system relies on a classical master oscillator power amplifier design. The first component is a fiber-based oscillator providing a broad

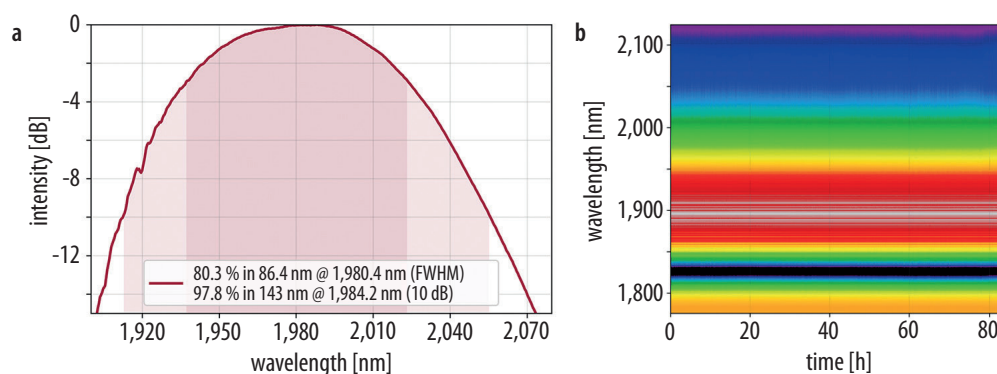


Fig 1 (a) oscillator spectrum, (b) long-term measurement of spectral stability, spectral evolution in logarithmic scale

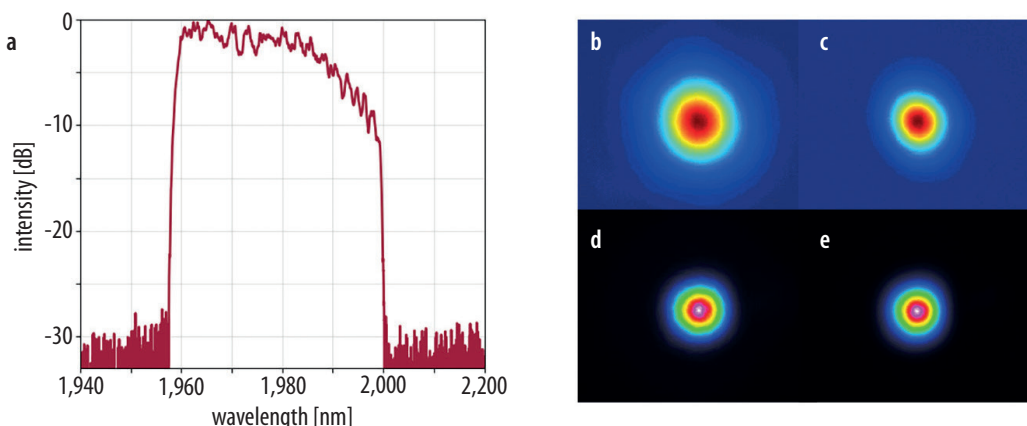


Fig 2 (a) spectrum behind the last preamplifier stage, (b) beam profile behind AOM at 10 W, (c) beam profile behind AOM at 40 W, (d) beam profile behind isolator at 10 W, (e) beam profile behind isolator at 40 W

spectrum around 2 μm (see Fig. 1a). The focus in the design of the oscillator was a long lifetime as well as a stable spectral output to maintain peak-power stability in the laser output as required by delicate materials processing applications (see Fig. 1b).

Subsequently, pulses are derived from the 25 MHz oscillator repetition rate and further amplified in Tm-doped fiber preamplifiers, maintaining a broad spectrum with acceptable modulation (see Fig. 2a) while also being stretched dispersively to ~ 1.5 ns of pulse duration.

Tm-doped silica fibers are also employed at the heart of this laser system – the main amplifier. These fibers exhibit a broad amplification band spanning from 1,800 to 2,100 nm. Efficiently pumped by high-power diode lasers emitting around 790 nm, they achieve slope efficiencies exceeding 70 %, exploiting cross-relaxation processes. Before entering the pulse compressor unit, the pulses are sent through an externally controllable acousto-optic modulator (AOM) and an optical isolator. Both components have just recently become available with the capability

to handle high average powers without disturbing the beam profile due to thermal lensing (see Fig. 2b-e).

After the compressor, the laser emits pulses with an energy exceeding 100 μJ . These pulses are centered at a 1,980 nm wavelength and have a pulse duration of slightly less than 400 fs while being dispersively tunable up to 5 ps. On request, the system can be modified to provide longer pulse durations between 1 ps and 1 ns. At full energy, the laser still operates at a repetition rate of up to 150 kHz, resulting in a substantial average power output of >15 W (see Table 1

Central wavelength	approx. 1,980 nm
Repetition rate	single shot to 25 MHz
Pulse energy	up to 100 μJ (at up to 150 kHz)
Average power	up to 15 W
Pulse duration	<400 fs – 5 ps adjustable, or up to 1.5 ns
Polarization	linear
Beam quality	close to diffraction-limited, $M^2 < 1.3$
RIN slow (average power)	<1 % RMS [1/(24 hours) - 1 Hz]
RIN fast (pulse energy)	<2 % RMS [1 Hz - $f_{\text{rep}}/2$]
Beam pointing	<10 μrad RMS
Dimensions, mass	800 mm $\times$ 300 mm $\times$ 400 mm, <100 kg
Logging	logging of all operation parameters via control software, remote monitoring and service access
Additional features	Turnkey reliability, software-controlled parameters, optical isolation, shutter, RTC6 interface, software-API

Table 1 specifications of the newly-developed activeTwo-15 laser system

Company

Active Fiber Systems

With cutting-edge research and continuous improvements, the solutions of Active Fiber Systems range from compact designs to complex beamlines, all based on fiber amplifier technology developed in Jena. The company's ultrashort-pulse fiber lasers have been refined in collaboration with Jena's top research institutes, resulting in groundbreaking advancements and multiple world records. As part of the Trumpf group, AFS has surpassed these achievements to become a global leader in high-power laser development.

www.afs-jena.de

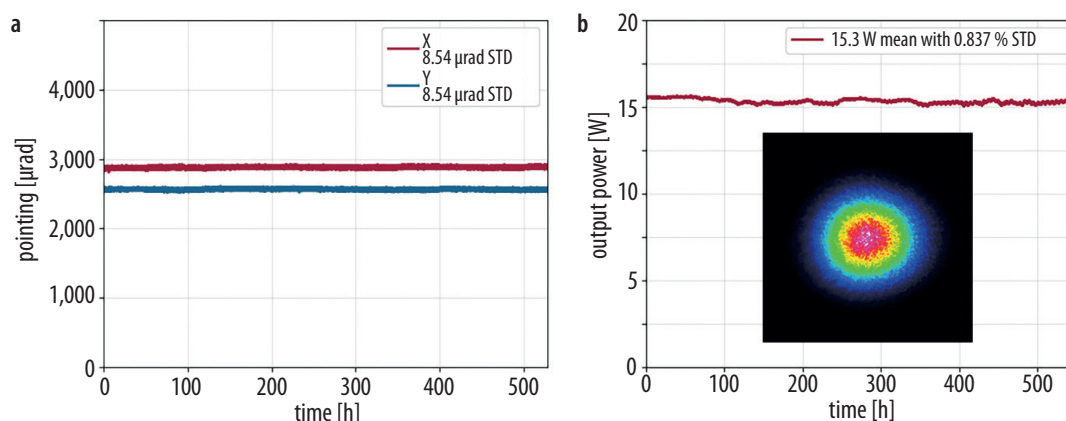


Fig 3 (a) long-term measurement of pointing fluctuations at full output power, (b) long-term measurement of output power, inset: beam profile at full output power

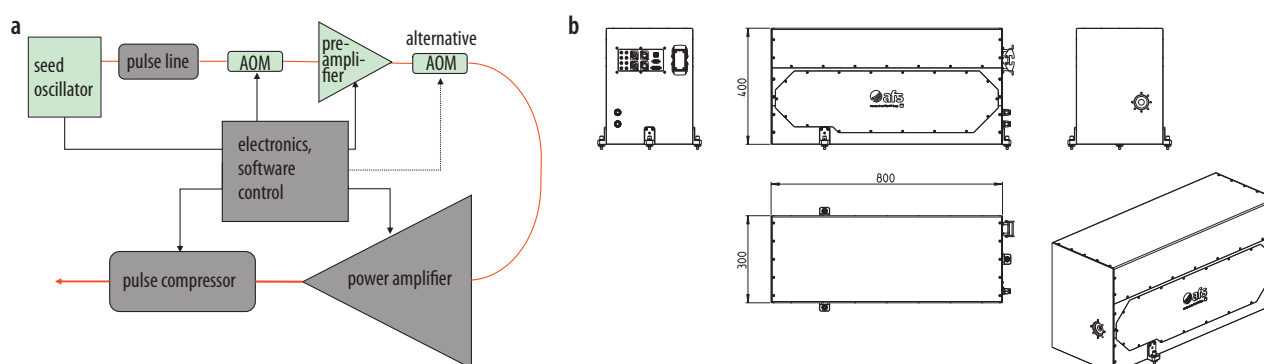


Fig 4 (a) schematic design of the CPA system, (b) technical drawing of the laser system

for full specification). This high repetition rate allows for efficient throughput in industrial applications, making it suitable for continuous production lines.

The device is engineered to operate without the need for vacuum equipment. It also avoids water-vapor absorption, ensuring consistent performance. The result is a nearly diffraction-limited beam quality and excellent pointing stability – essential for precision tasks. This outstanding long-term stability, also of the average power, ensures reproducible processing results in even the most demanding environments (see Fig. 3).

The system is built with a modular layout to ensure worry-free ser-

vice access (see Fig. 4a). The compact dimensions enable integration into most machines (see Fig. 4b).

Summary

The activeTwo-15 industrial-grade laser system (see Fig. 5) allows precise adjustment and monitoring of critical process parameters, including pulse energy up to 100 μJ , and repetition rates between a single shot and 25 MHz. Notably, this laser operates without the need for vacuum equipment, avoiding water-vapor absorption. As a result, it achieves nearly diffraction-limited beam quality and exceptional pointing stability. Engineered for industrial-grade performance, the laser is optimized for

long-term operation. Its packaging is well suited to seamless integration into laser machines used for materials processing. The laser's parameters make it particularly well suited to semiconductor processing tasks, such as micro welding or filament cutting.

*

We gratefully acknowledge the support provided by the PTJ and BMBF within the framework of RUBIN-UKPiño (03RU2U031A), as well as EU and BMBF within the framework of MIMOSA & RoeLaMat (101046651 & 03TN0056C).

DOI: 10.1002/phvs.202400036

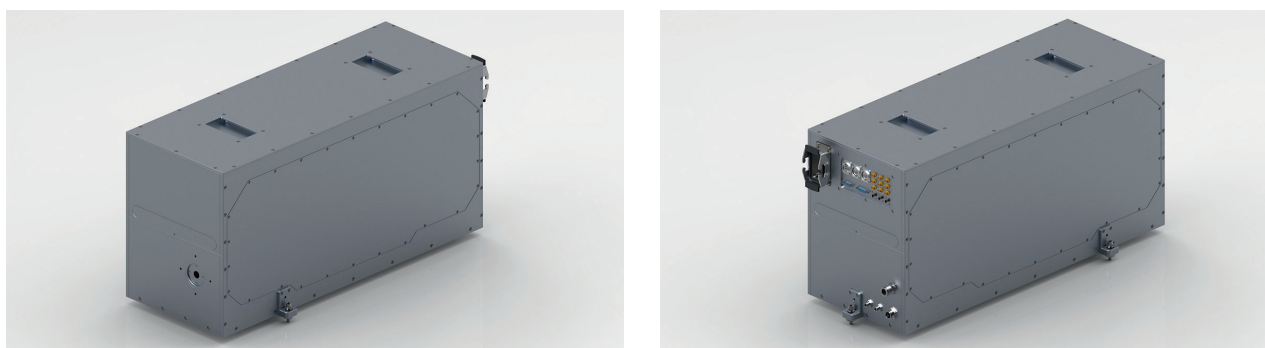


Fig 5 rendered view of the second generation of our compact 2- μm laser with a volume of only $800 \times 300 \times 350 \text{ mm}^3$ (front and back)

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Authors

Christian Gaida did his PhD in physics in Jens Limpert's group at the Friedrich-Schiller-University in Jena. After starting as a project manager, he is now the head of the R&D department at Active Fiber Systems.



Tobias Heuermann is the technical manager for thulium-based lasers at Active Fiber Systems. He is currently completing his PhD thesis at Friedrich Schiller University in Jena.



Sven Breitkopf is head of sales at Active Fiber Systems. He received his diploma degree in general physics

and his PhD degree from the Friedrich-Schiller-Universität in Jena, Germany in 2011 and 2018 respectively. His research interest focused on high average power, ultrafast fiber lasers, enhancement cavities, and coherent pulse combining techniques. From April 2018 to April 2019 he was a project manager at Active Fiber Systems before being promoted to coordinate the global sales activities.



Tino Eidam is the CTO at Active Fiber Systems. He received his diploma degree in general physics and a PhD degree from the Friedrich-Schiller-Universität in Jena, Germany.



Further author

Jens Limpert, Friedrich Schiller University Jena

Active Fiber Systems GmbH, Dr. Sven Breitkopf, Ernst-Ruska-Ring 17, 07745 Jena, Germany; e-mail: publications@afs-jena.de, Web: www.afs-jena.de, [linkedin.com/company/active-fiber-systems-gmbh](https://www.linkedin.com/company/active-fiber-systems-gmbh)
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Optical Measurement Technology

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How laser material processing can benefit from OCT technology

A qualitative and quantitative analysis of ultrashort-pulse processing of glass

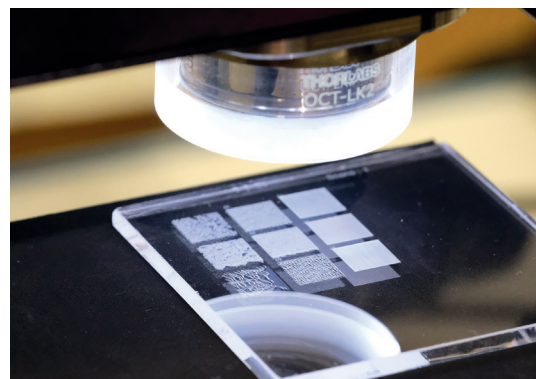
Ultrashort-pulse (USP) laser ablation enables the creation of freeform shapes that are challenging to produce with conventional optics manufacturing techniques. To maintain the industrial standards of many branches, it is crucial to not only consider material removal rates but also the surface quality and subsurface damage (SSD). This study investigates the SSD patterns generated in fused silica and quantifies key parameters such as the SSD depth by applying optical coherence tomography (OCT).

The work demonstrates the application of OCT technologies for the laser ablation of optically transparent materials. OCT is a powerful tool for 3D visualization as well as for analysis of the process. These insights deepen

the understanding of defect formation and can accelerate process optimization. The observations can further help to find the causes of different morphologies. Future work can benefit from a stronger correlation of other monitoring methods as well as simulative approaches.

Ernst Abbe University of Applied Sciences

Michael Seiler, Samson Frank, Dennis Thelemann, Oliver Elies, Pouria Teymori, and Jens Bliedner
 Department of SciTec
 Carl-Zeiss-Promenade 2
 07745 Jena
 Germany
 phone: +49 3641 205-749;
 e-mails: michael.seiler@eah-jena.de
samson.frank@eah-jena.de
 Web: www.ag-bliedner.de



USP laser-processed fused silica sample during measurement with a GAN621 spectral domain OCT system



<https://doi.org/10.1002/phvs.202400037>

SiC high-tech ceramics – a comparison of laser processes

Optimizing laser processes for SiC ceramics: focusing on precision, efficiency, and processing quality

Christian Rochholz & Andreas Meudtner



Source all images: LCP Laser-Cut-Processing

Extensive R&D applied various laser sources – from nanosecond VIS-wavelength to femtosecond IR and water-jet guided lasers – to enhance the quality and efficiency of laser structuring, fine cutting, and drilling of silicon carbide. Tests focused on surface roughness, cutting line precision, and high ablation rates. Challenges due to diverse material compositions, like diamond layers, required combined methods to develop viable approaches. To meet economic constraints, mechanical grinding was integrated with recurring laser processing.

Silicon carbide (SiC) and its variants – sintered SiC (SSiC), silicon infiltrated SiC (SiSiC), diamond SiC, et cetera – is a material that is very popular nowadays. The areas of application range from high-temperature applications such as the lining of steel furnaces and waste incineration plants to composite materials for components in gas turbines [1] and other refractory products. Other areas of application include sealing rings, soot filters and brake disks in the automotive industry as well as structural and functional

ceramics [2, 3]. The material owes this wide range of applications to its special properties in combination: very good oxidation and corrosion resistance, low density and a low thermal expansion coefficient meet high thermal conductivity as well as very high hardness and abrasion resistance [3].

One specific example is the components for pumps and other units for subsea applications developed as part of the SubseaSlide R&D project. The environmental conditions make the maintenance of the components used

there extremely difficult, which is why materials such as SiC-bonded diamond materials, which are extremely resilient and wear-resistant, are used [4]. However, the properties mentioned pose problems for mechanical manufacturing processes, which is why alternatives such as laser processing come into play here. In laser material processing, for example, technologies such as nanosecond pulsed laser processing [5], pico and femtosecond IR sources [6, 7] and water-jet guided laser beam processing [8] are used.

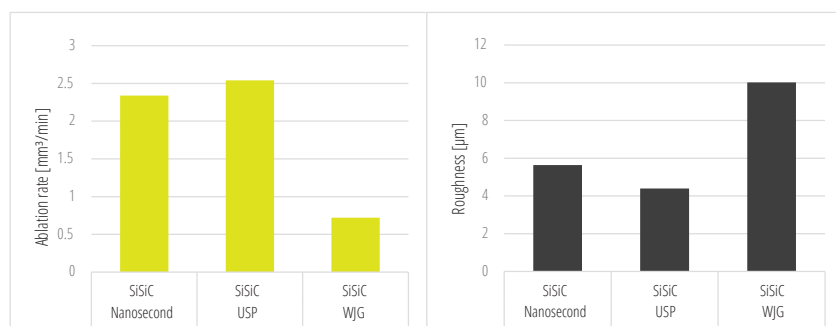


Fig. 1 Comparison of technologies in terms of ablation rate and roughness for structuring

Compared to other mechanical cutting and grinding processes, laser material processing is characterized by tool-free and contact-free processing without mechanical stress on the workpiece. Although the use of conventional, rather long-pulse nanosecond laser sources reduces the energy input and leads to minimal heat conduction effects, the process still belongs to the thermal processes in which the material is melted or directly vaporized in the processing zone [9].

Modern ultrashort-pulse laser material processing uses very short pulses – in the range of femtoseconds and picoseconds – in which the exposure time of the individual pulse in the material is so short that heat conduction effects do not occur or are so small that they can be neglected. It is therefore considered an athermal ablation process. Due to the short pulse durations, the penetration depth and therefore the removal per individual pulse in the material to be processed is less than with thermal processes. However, this increases the accuracy that can be achieved in comparison [9].

The water-jet guided (WJG) laser technology is characterized by the fact that a thin laminar water jet is generated into which a laser beam is threaded. Multiple reflections of the laser beam at the inner edges of the water jet ensure that the intensity distribution of the laser beam is approximately the same over the length of the water jet. In this way, the caustic effect typical of a laser beam is avoided, allowing vertical cutting edges ($< 1^\circ$) to be produced. Similar

to ultrashort-pulse processing, this is an ablative process. The additional cooling of the water jet reduces the thermal input into the material, which means that ceramics such as SiC can also be machined without cracks.

The tests for machining SiC were carried out as part of the funded SubseaSlide, SAPHIR and UKPino R&D projects.

Technology

The SiC laser processing methods that are compared here use nanosecond pulsed (ns), ultrashort-pulsed (USP) and water-jet guided laser radiation, as well as fusion cutting. The ns-pulsed system works with a maximum average power of 100 watts at 1 mJ pulse energy and with a pulse length of 120 ns at a wavelength of 355 nm. The diameter of the laser beam at the focus is 50 µm. The laser beam is positioned by means of scanner optics. The system also has an additional processing head that was used for the fusion cutting experiments. The cutting optics are operated with a solid-state laser (1,070 nm) in cw mode and provide a power of 1 kW. The focus is 60 µm and positioning is carried out using an x-y table.

The laser for ultrashort-pulse processing is characterized by pulses of up to 1 ps at a wavelength of 1,030 nm and a maximum average power of 100 W. The diameter of the laser beam at the focus is 60 µm and positioning is carried out in the same way as with the nanosecond laser using scanner optics.

The water-jet guided system uses a fiber laser with a wavelength of

1,070 nm. The diameter of the water jet and thus also the focus of the laser beam can be adjusted using different nozzles. Nozzles with a diameter of 50 – 80 µm were available for the experiments. As the quality of the water has a decisive influence on the processing result, it is filtered until it has a conductivity value of less than 0.1 µS/cm. An x-y table is used to position the workpiece relative to the water jet, as in the dry processing station.

Evaluation

A direct comparison of test sequences, laser parameters and their optimization makes little sense when comparing the technologies, as their physical modes of action differ too greatly. The processing results are therefore compared with each other.

As ablation processes, nanosecond pulsed, ultrashort-pulse, and water-jet guided technology are able to produce 3-dimensional structures using 2.5D machining. Important target parameters here are the removal rate, which determines how quickly a volume can be processed, and the quality of the processing surface that can be generated, which can be measured using roughness for example.

Company profile

LCP Laser-Cut-Processing

For more than thirty years, LCP has specialized in the laser fine machining of delicate, geometrically complex and sensitive microprecision components made of special materials. Our technical expertise, our R&D activities as well as the passion and creativity of our team drive us to produce new solutions for high-performance products in demanding high-tech applications. We have a wide range of laser technologies, mechanical machining processes and a network of cooperation partners at our disposal. Advice on technical feasibility and our service along the entire process chain are the basis for the satisfaction of the customers.

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Laser processes	Minimum pulse duration [µs]	Beam Positioning	Focal diameter [µm]
Fusion cutting	cw	x-y table	60
Water-jet guided (WJG) machining	10	x-y table	50 – 80
Nanosecond (ns) machining	0.12	scanner	50
Ultrashort-pulse machining (USP)	0.000001	scanner	60

Table 1: Overview of technologies with associated systems engineering

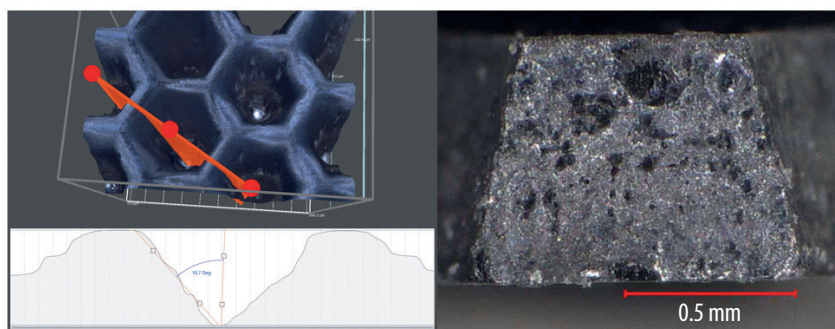


Fig. 1 shows the comparison of the technologies during structuring in terms of ablation rate (left) and roughness (right). It can be seen that the ablation rate for the nanosecond pulsed and the ultrashort-pulse system is significantly higher than for the water-jet guided technology. The ultrashort-pulse and nanosecond processing systems can provide significantly higher feed rates due to beam positioning using a scanner. In addition, the repetition rates for the machining/preferred parameters are higher – 10 kHz (ns), 400 kHz (USP), 500 Hz (WJG) – which results in a higher ablation rate overall.

A comparison of the roughness of the ablated surface shows the opposite picture. Here, the lowest values are achieved when processing using ultrashort-pulse technology ($R_a = 4.4 \mu\text{m}$), followed by the ns-pulsed system ($R_a = 5.64 \mu\text{m}$). The surfaces ablated using a water-jet guided laser beam have a significantly higher value in comparison with an R_a of $10.02 \mu\text{m}$. The reason for this lies in the selected track spacing. This is $20 \mu\text{m}$ for the preferred parameters of ns and ultrashort-pulse machining and $40 \mu\text{m}$ for water-jet guided technology. The track spacing has a significant influence on the roughness achieved when processing with a pulsed laser: the smaller the track spacing, the lower the roughness [10]. To remove a given geometry, the total processing time increases with reduced track spacing, which has a negative effect on the ablation rate. Fast, scanner-based systems can compensate for this bet-

ter than the slower systems with an x-y table.

In a comparison of the technologies, structuring using ultrashort pulses achieves the highest ablation rate ($2.54 \text{ mm}^3/\text{min}$) with the lowest roughness ($4.4 \mu\text{m}$) within the process parameters considered for this publication. For pure structuring tasks on SiC materials, ultrashort-pulse technology is the preferred variant.

A side effect during removal using ns and ultrashort-pulse technology is the resulting taper. Vertical cuts are possible due to the constant diameter in the working area of the water-jet guided technology [11]. However, the removal of SiC also generates a taper with this process (Fig. 2b).

Fig. 2 shows a comparison of the resulting taper when structuring using ultrashort-pulse and water-jet guided technology. Due to the process, nanosecond and ultrashort-pulse processing requires a widening of the kerf with additional tracks for material thicknesses $>100 \mu\text{m}$. The tests showed a taper of 11° for the preferred parameters, which would result in a kerf widening of 1.94 mm for a material thickness of 5 mm . Depending on the machining geometry, this is not desired or possible, which is why nanosecond and ultrashort-pulse technology are not considered for the cutting tests.

Several passes are required to cut the SiC for material thicknesses from 0.5 mm (fusion cutting) and 0.2 mm (water-jet guided processing). The required number of passes depends

Fig. 2 Taper created during structuring: (a) ultrashort-pulse, (b) water-jet guided laser machining

on the material thickness and is ten to fifteen for both processes with a material thickness of 2 mm . An exact number of passes cannot be determined as the number can vary slightly even on the same substrate. One reason for this may be minimal, spatially limited deviations that occur as a result of the material production or as local deviations in the material composition and grain structure.

Fig. 3 shows a comparison of the cutting edge of the water-jet guided technology (3a) and fusion cutting (3b). The measured cutting-edge angle is 0.18° (material thickness $t = 5 \text{ mm}$) for the water-jet guided technology and 0.72° (material thickness $t = 1 \text{ mm}$) for fusion cutting. A determination of the roughness of the cut edge resulted in an average value of $R_a = 1.585 \mu\text{m}$ (min/max = $0.997 \mu\text{m} / 3.553 \mu\text{m}$) for the water-jet guided technology and $R_a = 2.952 \mu\text{m}$ (min/max = $1.585 \mu\text{m} / 4.952 \mu\text{m}$) for fusion cutting.

Conclusion

A direct comparison of influencing parameters does not lead to a satisfactory result when comparing the different technologies, as the effects of each differ too greatly. It therefore only makes sense to compare the processing results with each other. Depending on the objectives, each technology has its own purpose, whereby the strengths of the individual processes can be combined.

In terms of material removal, nanosecond pulsed and ultrashort-pulse

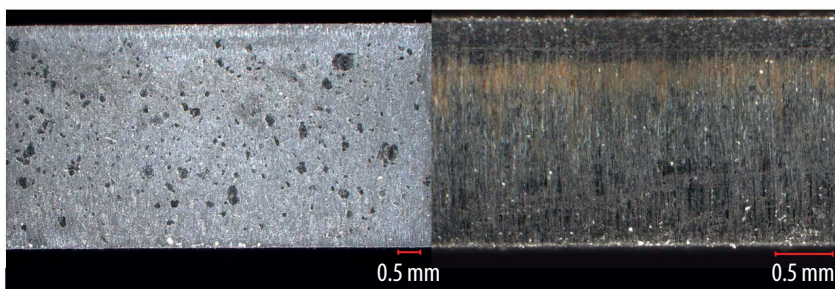


Fig. 3 Comparison image of cutting-edge using (a) water-jet guided technology and (b) fusion cutting



Fig. 4 Combined processing using ultra-short-pulse (trenching) and water-jet guided technology (drilling) from SiC

technologies have an advantage. Due to the high feed rates that can be achieved here thanks to the scanner optics, significantly higher ablation rates are possible with low roughness. For pure cutting geometries, fusion cutting and water-jet guided technology have the advantage, whereby almost vertical cutting edges ($< 1^\circ$) can be produced. The appropriate process must be selected depending on the geometry to be machined. It is possible to combine different processes in order to achieve the best possible machining result. See Fig. 4 for an example.

DOI: 10.1002/phvs.202400038

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Authors

Christian Rochholz has several years of experience in laser material processing. He joined LCP in 2024 and works there as an application engineer in technology, where he is responsible for the area of water-jet guided technology. He studied laser and optotechnology at the Ernst Abbe University of Applied Sciences in Jena.

Further author

Andreas Meudtner, LCP Laser-Cut-Processing GmbH

M. Eng. Christian Rochholz, Dipl. Ing. Andreas Meudtner, LCP Laser-Cut-Processing GmbH, Heinrich-Hertz-Str. 16, 07629 Hermsdorf, Germany, phone: +49 36601 932773, e-mail: christian.rochholz@lcpghmbh.de, Web: www.lcpghmbh.de, [linkedin.com/company/lcp-laser-cut-processing-gmbh](https://www.linkedin.com/company/lcp-laser-cut-processing-gmbh)



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Dielectric material processing with ultrashort pulses

Optimizing ablation and scribing of dielectric materials through customizable burst modes and wavelength selection

Deividas Andriukaitis, Mantvydas Jašinskas, Paulius Gečys, and Christian Bischoff



Fig. 1 Femtosecond laser FemtoLux 30 alongside its 2024 Prism Award

Femtosecond lasers have become essential tools in material processing. Thanks to their ultrashort pulse duration, these lasers can process a wide range of materials without causing significant thermal effects, leading to superior quality. Dielectric materials, especially glass and ceramics, are among those that benefit the most from femtosecond laser technology. Traditional processing methods often struggle with these materials, but femtosecond lasers provide a solution with high precision and quality.

Continuous innovations are making femtosecond lasers even more versatile. One such innovation is burst mode, which outputs bursts of pulses at MHz/GHz repetition rates. Burst mode splits a single high-energy pulse into multiple pulses, optimizing the laser's power and increasing the process throughput. In this article, the FemtoLux 30 industrial femtosecond laser is employed in glass and ceramics processing using MHz/GHz burst mode, resulting in a throughput increase ranging from several to tens of times.

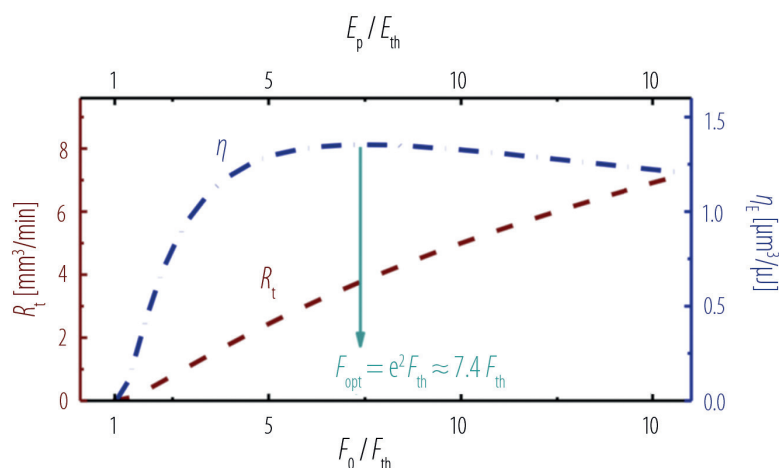
Towards utilizing the full laser potential

It is well known that femtosecond lasers are highly effective tools for processing brittle materials such

as glass and ceramics. These ultrashort-pulse lasers enable the precise machining of dielectric materials, and with pulse durations in the hundreds of femtoseconds, the resulting quality is unparalleled [1]. However, one challenge with femtosecond laser processing is achieving higher throughput, which still lags behind traditional methods [2]. To address this, continuous advancements in ultrashort-pulse laser technology have increased average optical power to several kilowatts [3]. Nevertheless, higher average power alone does not directly translate to increased throughput. There is an optimal fluence at which the most efficient material ablation occurs, $7.4 \phi_{th}$, where ϕ_{th} is the material ablation threshold.

Several approaches can be taken to achieve this optimal fluence. One method is to increase the pulse repetition rate while lowering the pulse energy, thereby bringing the fluence closer to the desired value. However, there is a limit to how much the repetition rate can be increased, as excessively high rates may degrade quality and cause ablation particle shielding, ultimately reducing throughput [5]. Another approach is to increase the beam diameter, which decreases the fluence to the optimal level. A key advantage of this method is that it allows full utilization of the laser's power without complicating the processing setup, unlike beam splitting. However, increasing the beam diameter sacrifices precision, which can be a critical factor

Source all images: EKSPLA



► **Fig. 2** Ablation efficiency and ablation rate dependence on fluence [4]

in applications requiring small feature sizes.

Another method for achieving optimal fluence is to split high-energy pulses into multiple smaller pulses using a burst mode, which operates with intraburst repetition rates in the MHz and GHz range. This approach, combining pulse splitting with high intraburst repetition rates, has proven beneficial for material micromachining applications [6–8]. However, further studies are needed to fully understand the mechanisms behind the increase in process throughput when using MHz/GHz burst mode. A key challenge in conducting such studies is the limited availability of laser sources that offer various configurations of MHz/GHz burst modes. To address this, an active fiber loop was

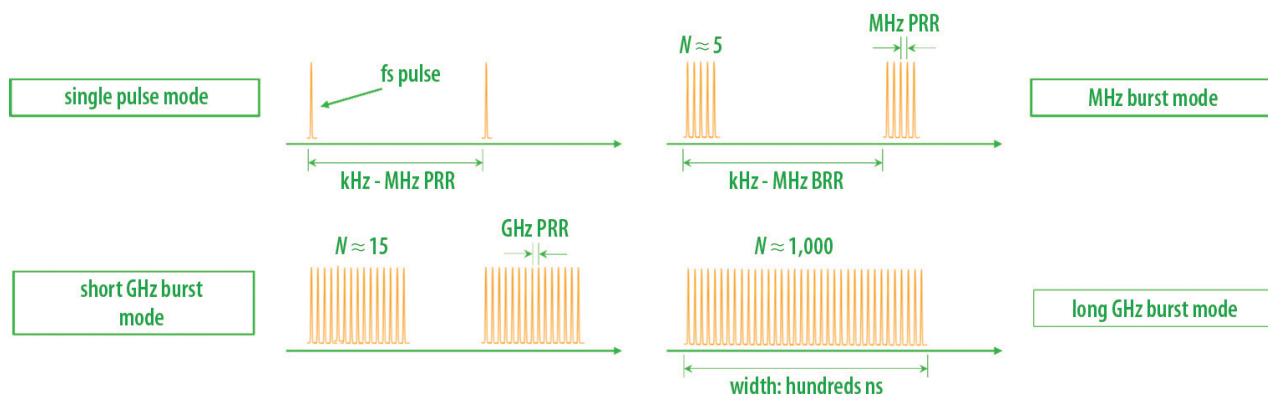
developed, enabling the formation of different GHz bursts. This was integrated into the FemtoLux 30 industrial femtosecond laser, which was utilized in this study of dielectric materials processing [9].

Active fiber loop (AFL) for flexible GHz burst formation

The patent-pending active fiber loop (AFL) technology was developed to provide unparalleled flexibility in selecting burst parameters. This all-in-fiber AFL system consists of key components such as the AOM1-3 (acousto-optical modulators), an FC (fiber coupler), a YDF (ytterbium-doped fiber), a CFBG (chirped fiber Bragg grating), and an LD (laser diode), cf. Fig. 4. The GHz burst formation technique works by splitting and delaying pulses from

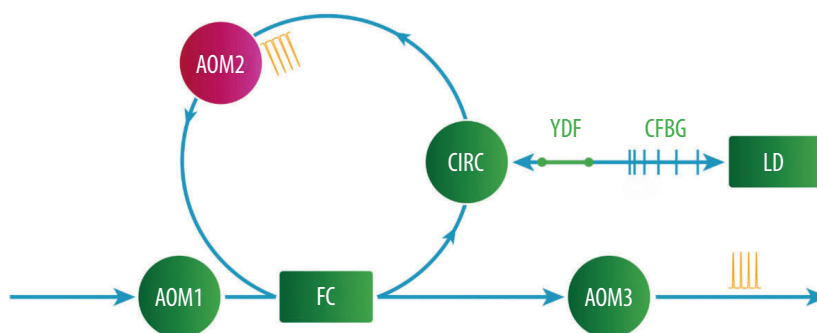
the MHz master oscillator. With each round trip, delayed replicas from previous cycles are combined with an undelayed replica of the next input pulse. This allows the AFL to generate GHz bursts with broad tunability in the number of pulses per burst, using AOM3 as a pulse picker to select bursts with the desired pulse count.

The AFL method for generating GHz and combined MHz+GHz bursts has been successfully integrated into the FemtoLux 30 industrial femtosecond laser system. In the GHz burst regime, AFL technology allows the formation of 2.2 GHz bursts containing 2 to 22 pulses and 44 to 1,100 pulses per burst (Fig. 5a and 5b). Additionally, the AFL enables operation in a combined MHz+GHz burst mode, offering a 50 MHz burst mode with 2 to 10 pulses and a 2.2 GHz



▲ **Fig. 3** Possible operation modes of an ultrashort laser source dependence on fluence [4]

► **Fig. 4** Schematic of the active fiber loop method



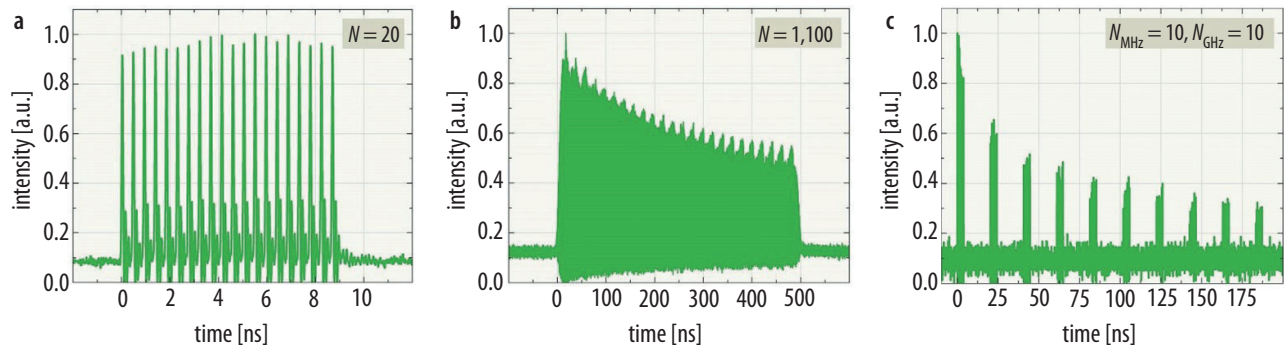


Fig. 5 FemtoLux 30 different GHz burst operation modes: (a) short GHz burst, (b) long GHz burst, (c) combined MHz and GHz burst

burst mode with 2 to 22 pulses per burst (Fig. 5c). As a result, the FemtoLux 30 stands out as the only laser on the market providing unmatched versatility in burst mode selection. The system also features innovative direct refrigerant cooling technology, ensuring zero maintenance. With only two main components – the laser head and the

power supply – connected by an umbilical cable, the FemtoLux 30 is an ideal solution for a wide range of micromachining applications.

Burst modes in fused-silica glass

The influence of GHz and MHz+GHz burst modes on ablation rates was

examined by milling $2 \times 2 \text{ mm}^2$ areas. A beam approximately $20 \mu\text{m}$ in diameter was focused onto the sample, which was scanned using bidirectional hatching, with the scanning angle adjusted by 33 degrees for each layer. The focus position was changed with each layer to maintain focus on the processed surface. The FemtoLux 30 operated with

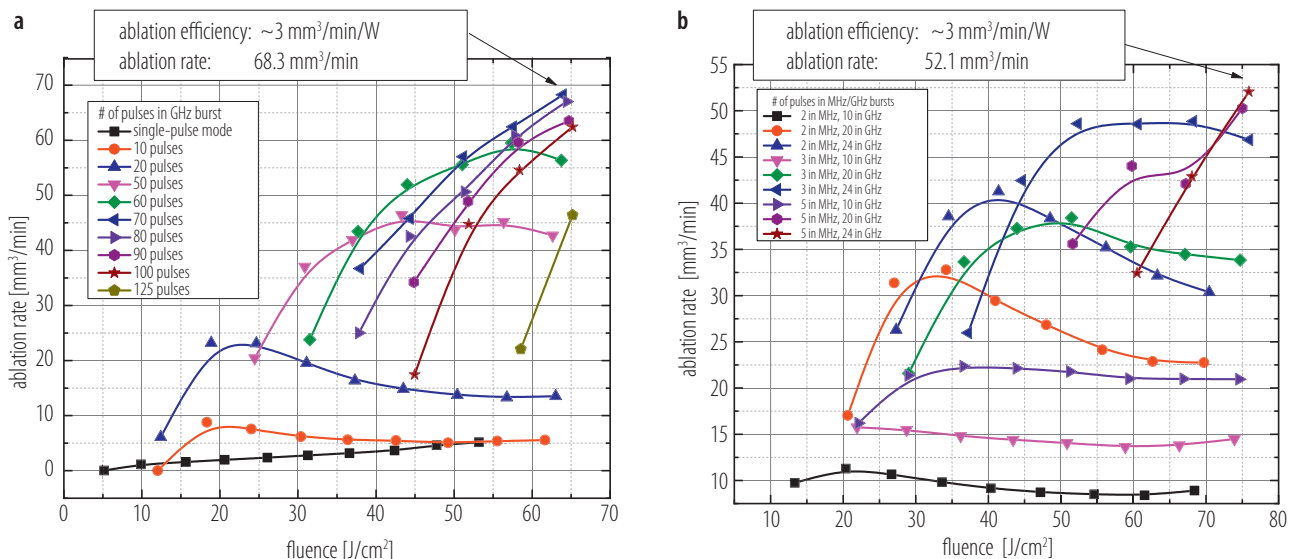


Fig. 6 (a) ablation rate depicted against fluence for GHz burst and (b) MHz+GHz burst

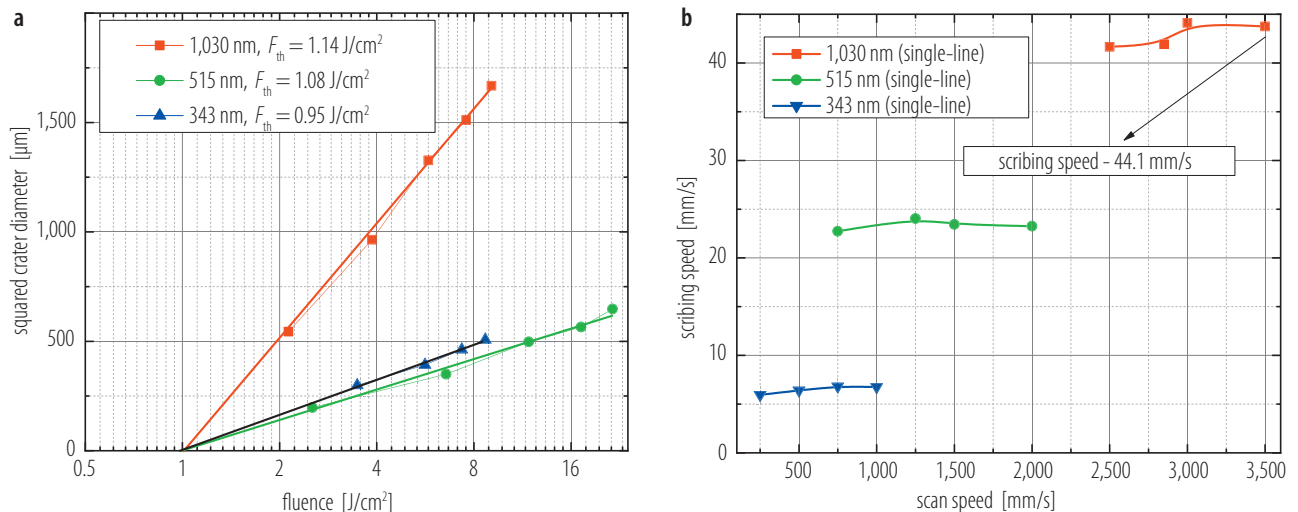


Fig. 7 (a) Ablation threshold measurement for different wavelengths, (b) scribing speed investigation by iterating scanning speeds

a pulse duration of 298 fs, a repetition rate of 200 kHz, and a wavelength of 1,030 nm. After processing, the depth of each square was measured, and the ablation rate was calculated.

In the GHz burst mode, the ablation rate consistently increased as the number of pulses in the burst rose, reaching a peak ablation rate of 68.3 mm³/min with 70 pulses per burst (Fig. 6a). In the MHz+GHz burst mode, the ablation rate similarly increased with the number of pulses in both MHz and GHz bursts, achieving a maximum ablation rate of 52.1 mm³/min (Fig. 6b), which was slightly lower than that of the GHz burst mode. The results show that the GHz burst mode is more effective in milling fused-silica glass than the MHz+GHz burst mode, increasing the ablation rate by 13.2 times compared to single-pulse mode.

Scribing of ceramic plates with femtosecond pulses

Ceramics are widely used dielectric materials, valued for their exceptional properties such as high thermal conductivity, electrical insulation, mechanical strength, and resistance to corrosion and wear. However, conventional mechanical processing methods often require significant force, which can lead to cracks and potential substrate breakage. Femtosecond lasers offer a high quality, precise solution for processing hard and brittle materials like ceramics.

In this study, the FemtoLux 30 was tested for scribing ceramic materials, specifically in the formation of grooves. A comprehensive investigation was conducted to evaluate scribing speeds and quality using 1,030 nm, 515 nm, and 343 nm wavelengths. The ablation thresholds for these wavelengths were first examined. Craters were formed by irradiating the ceramic plate with single

femtosecond pulses at each wavelength. The diameter of these craters was measured, squared, and depicted graphically, allowing for the calculation of ablation thresholds. The results showed ablation thresholds of 1.14 J/cm² for 1,030 nm, 1.08 J/cm² for 515 nm, and 0.95 J/cm² for 343 nm. The observed decrease in ablation thresholds at shorter wavelengths is attributed to the increased efficiency of multiphoton absorption and other nonlinear effects, which become more pronounced with higher harmonics [10].

After calculating the ablation thresholds, the repetition rate was increased to adjust the fluence to its optimal value $7.4 \phi_{th}$. The scanning speed was then iterated for different wavelengths to identify the maximum scribing speed. The highest scribing speed achieved was 44.1 mm/s for 1,030 nm, which decreased to 25 mm/s for 515 nm and 6.82 mm/s for 343 nm. The primary reason for this drop in scanning speed at 515/343 nm is the lower average laser power available at these wavelengths. It is also worth noting that while the scribing speed at 1030 nm was the highest, the heat-affected zone (HAZ) was also the largest, measuring $8.23 \pm 1.11 \mu\text{m}$. By using the 515 and 343 nm wavelengths, the heat-affected zone was significantly reduced to $5.62 \pm 1.07 \mu\text{m}$ and $4.88 \pm 0.59 \mu\text{m}$, respectively.

Prize-winning industrial femtosecond laser

The FemtoLux 30 femtosecond laser system was used in all the studies discussed above. Early in 2024, this system received one of the most prestigious honors in the photonics community – the Prism Award. This recognition was earned due to several innovations integrated into the laser that have significantly advanced micromachining

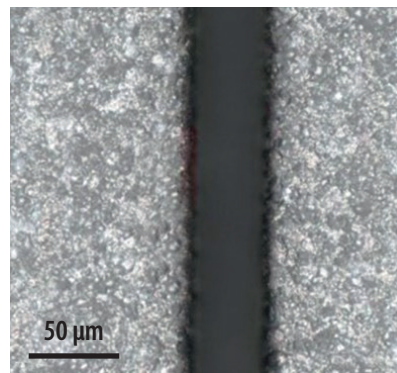


Fig. 8 Microscope image of a ceramic plate that was scribed with a femtosecond laser

applications while simplifying the use of these complex systems.

The first feature of the FemtoLux 30 is its use of the active fiber loop (AFL) technology, making it the only laser on the market capable of extensive tunability in generating GHz bursts – ranging from 2 to 1,100 pulses per burst. Additionally, the AFL provides precise control over the burst amplitude, a must have for applications requiring flexibility.

Another innovative aspect is the direct refrigerant cooling system. This method addresses the lack of innovation in cooling femtosecond lasers, and uses a hermetically sealed system with a refrigerant agent, efficiently cooling the laser without the need for traditional water-based methods. This eliminates the need for a water pump, a component prone to failure, and removes the bulky chiller, eliminating system maintenance and minimizing the laser's footprint. These innovations make the FemtoLux 30 not only highly reliable but also easier to install and operate, further increasing its appeal in industrial micromachining applications.

DOI: 10.1002/phvs.202400040

Companies

Ekspla

With more than thirty years' experience in making laser systems, Ekspla from Vilnius, Lithuania, designs and manufactures advanced lasers systems. With a key strength in tailoring products to specific requirements, the company has gained recognition from eighty of the top one hundred universities worldwide. The main product line includes femtosecond, picosecond, and nanosecond lasers for industrial applications, as well as tunable wavelength, spectroscopy, and high-intensity laser systems for scientific applications.

www.ekspla.com

TOPAG Lasertechnik

Incorporated in 1993 and located in Darmstadt, Germany, TOPAG sells pulsed solid-state lasers for scientific and industrial applications, and distributes and services Ekspla lasers in Germany and Austria. Other products include lasers from other manufacturers, ultrashort pulse metrology, spectrometers, infrared viewers, optics and crystals. TOPAG also develops and manufactures innovative laser beam-shaping optics for the optimization of laser processes.

www.topag.de

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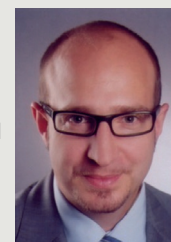
Deividas

Andriukaitis is an OEM laser sales manager for Ekspla, having received his Masters' degree in laser technology from Vilnius University's faculty of physics in 2022. He is very interested in femtosecond lasers and material micromachining, especially for industrial applications. Deividas develops new femtosecond laser solutions that meet the needs of industrial clients.



Christian

Bischoff has a diploma in physical engineering from the Technical University of Applied Sciences Mittelhessen, and a Masters' degree in optical technology and image processing from the Darmstadt University of Applied Sciences. Since receiving his diploma in 2008, he has been working at Topag Lasertechnik, Darmstadt as a sales and development engineer for USP lasers and laser beam shaping. He is currently also doing his doctorate on laser-based manufacturing in Prof Lasagni's group at the Technical University of Dresden.



Further authors

Mantvydas Jašinskas, EKSPLA UAB and Center for Physical Sciences and Technology, Vilnius, Lithuania

Paulius Gečys, Center for Physical Sciences and Technology, Vilnius, Lithuania

Deividas Andriukaitis, EKSPLA UAB, 237 Savanorių Av., 02300 Vilnius, Lithuania; phone: +370 604 53184; e-mail: d.andriukaitis@ekspla.com, Web: www.ekspla.com ■ Christian Bischoff, TOPAG Lasertechnik GmbH, Nieder-Ramstädter Str. 247, 64285 Darmstadt, Germany; phone: +49 6151 4294423; e-mail: bischoff@topag.de, Web: www.topag.de

Optical Components and Systems

Preview – read the full article in PhotonicsViews issue 1/2025



PARMS coating technology for UV to IR laser applications

Improved technology for high-precision optical coatings fabrication in mass production



View into the process chamber (Source: I-Photonics)

Reactive sputtering using a medium frequency (MF) dual magnetron source is an advanced technique widely employed in various thin film deposition applications. For the production of high-quality optical filters based on

oxides with low losses, it is crucial to exclude any form of arcing, including both strong arcs and microarcs. These requirements are solved by plasma-assisted reactive magnetron sputtering (PARMS), which also provides a high deposition rate contributing to the economically efficient production of high-end optical filters.

Traditionally, the principle of PARMS is a two-step process. First, a thin oxide layer is deposited with a controlled oxygen deficiency. This is followed by an RF plasma-assisted process where reactive oxygen is used to transform the sputtered layer into a stoichiometric oxide layer. This process is repeated until the desired final layer thickness is achieved and stopped by a time control or optical monitoring system.

This conference contribution and article highlights the capability of the new PARMS-based Meridian coater, developed by I-Photonics UAB, to produce high-performance optical coatings using $\text{Ta}_2\text{O}_5/\text{SiO}_2$ and $\text{Nb}_2\text{O}_5/\text{SiO}_2$ oxide pairs. The Meridian coater features several enhancements that improve the reproducibility and quality of thin-film coatings, providing precise optical properties in a range from UV to IR wavelengths, making it suitable for mass production.

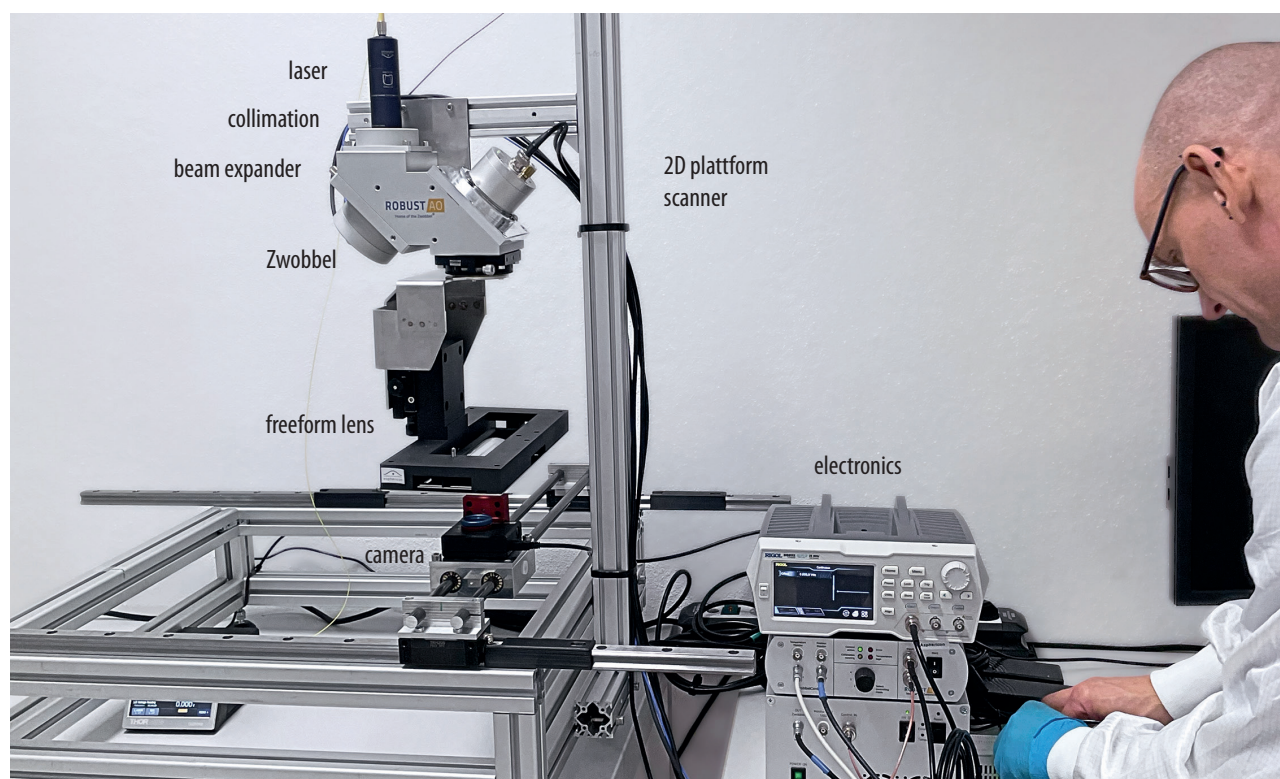
I-Photonics UAB

Aliaksandr Myslivets, Nadzeya Khinevich,
Eugene Hohlov
Parko st. 3, Avižienių k., 14180 Vilnius
Lithuania
phone: +370 674 62174
e-mail: a.myslivets@i-photonics.lt
Web: www.i-photonics.lt

Ultraviolet line structuring of large solar wafers

Combining freeform optics and deformable technology for minimized line widths

Henrike Schlutow, Ulrike Fuchs, and Claudia Reinlein



Ultrashort-pulsed lasers are ideal for material processing by welding, marking, and cutting. Scanning systems are crucial for large substrates. We introduce a novel UV line structuring method using deformable mirror technology and freeform optics. This approach aims to improve processing times on large substrates, especially for M12 solar wafer processing. By using a freeform lens and a Zwobbel deformable mirror, we achieve extended processing fields and high scan frequencies. The paper explores optical designs, their robust optomechanical implementation for prototyping, and setup characterization.

Solar cell contact opening (laser contact opening, LCO) is a crucial process in the production of modern solar cells, especially for PERC and TOPCon technologies. This process involves precise laser processing to create small openings in the cell's passivation layer [1], improving the contact between the conductive layers and the metal contacts. This step is essential to enhance the electrical efficiency of the cell and optimize the

module's overall performance, which is particularly important for larger wafers such as M12.

Spot sizes of less than $10\ \mu\text{m}$ are required for precise laser processing, such as contact opening in solar cells, regardless of the wafer size. The use of long focal lengths to cover larger scan fields typically results in larger spot sizes, creating a conflict [2]. Specialized optical systems are required to overcome this trade-off between field

▲ System setup with Zwobbel deformable mirror and freeform lens

size and precision, and to achieve the necessary small spot sizes. The scan speed and processing efficiency can be significantly increased by scanning with a line rather than a point. This method allows for faster and more efficient laser processing, enhancing overall throughput and productivity, which are espe-

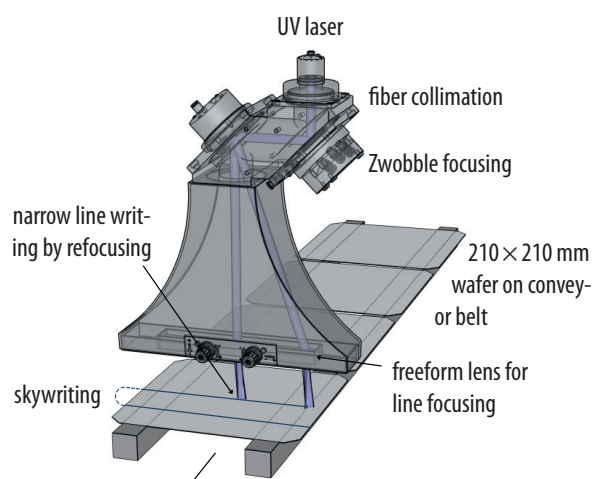


Fig. 1 PV line focus UV (Source: Robust AO)

cially important when handling larger wafers like M12.

Conventional off-the-shelf f-theta optics cannot meet these combined requirements. Therefore, a novel solution combining freeform optics with dynamic focusing technology is being introduced. This advanced approach addresses the need for both precision and efficiency in large-scale laser processing. Fig. 2 depicts the parameter range for both cases.

Optical design of line scanner lens

Line foci are usually generated with cylindrical or acylindrical lenses. In a classical setup, the length of the focal line is equal to the diameter of the incoming beam. To extend the line length, it might seem possible to use a long cylindrical lens and to scan the light across the long axis. However, this is not possible if a system with a scanning mirror is used because then the light hits the lens at different angles. The center thickness and lens curvature, projected onto the slanted light path, changes with the beam angle and thus inhibits sharp focusing on a

flat substrate. This was experimentally tested for LCO [1]. Freeform lenses, with the additional degrees of freedom, can account for slanted incoming beams and are therefore an ideal solution for this application. The freeform lens is combined with a deformable mirror for optimal manufacturability of the freeform lenses, which is important to achieve the extremely high surface quality needed for UV applications.

For the design presented in the following, the contributions of the mirror and the freeform are perfectly balanced for a robust solution. The freeform lens is described via a base curvature, conic constant and polynomials in x and y coordinates with a plano back side.

The optical layout is shown in Fig. 3: a collimated beam first hits the deformable mirror and is thereby directed to the scanning mirror. Depending on the mirror's angle, the light is focused by different segments of the freeform lens. For optimal performance, the mirrors deformation is coupled to the scanning mirror's deflection angle.

The optical model for the deformable mirror is a biconic surface with different radii of curvature along the long

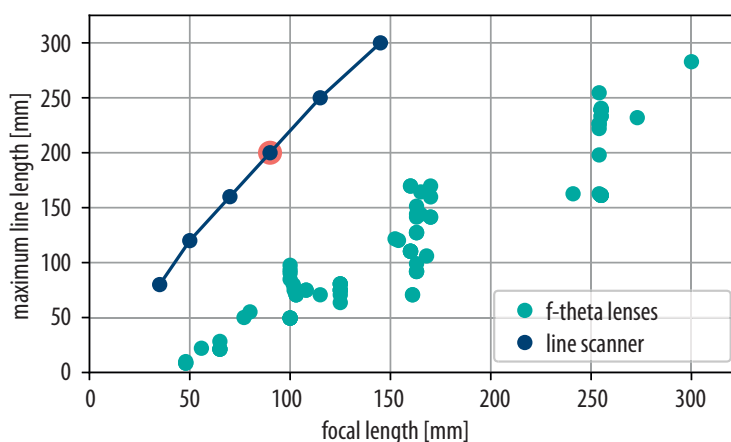


Fig. 2 maximum line lengths achieved by a selection of commercially available f-theta lenses with different focal lengths (green) and the range of line lengths achieved by the line scanner solution presented in this paper (blue). Highlighted in red is the solution selected for M12 wafer structuring

and short axis. The values were determined by taking surface measurements with a MarForm MFU 200 Aspheric 3D. The curvature values are shown in Fig. 4.

With the design solution presented above, a field of >210 mm is obtained, enabling the processing of the largest wafer sizes currently produced by photovoltaic manufacturers (M12).

Spot diagrams (see Fig. 5) demonstrate the focusing ability of the line scanner with a deformable mirror and freeform lens. The lines are well below 10 μm , which is necessary for the best performance of the contact opening process.

Practical evaluation

The practical evaluation served to prove the usability of the deformable mirror technology for UV applications, its capability to cope with the highest scan speed as needed by solar wafer production, and the resulting 10 μm narrow spots.

For reasons of space-saving and particularly fast focusing, we selected a specific deformable mirror (Zwobbel). This mirror membrane is deformed by a piezoelectric actuator, which means

Companies

Asphericon

Asphericon is a leading global manufacturer specializing in aspheric optics. With expertise in precision optics, they produce high-quality aspheres, freeform surfaces, and optical systems for a wide range of applications, including laser technology, imaging, and metrology. Through continuous innovation, Asphericon provides customized optical solutions that meet the most demanding industry standards, ensuring high performance and precision.

www.asphericon.com

Robust AO

Robust AO is the solution provider for dynamic beam shaping by fast focusing units under the ZWOBBEL brand name. By combining deformable mirror and innovative sensor technology, the fastest systems for high-power IR, CO₂ and UV lasers can be offered. As a result, the company's solutions accelerate processes and improve machining quality in industrial solutions for laser cutting, laser welding, additive manufacturing and laser surface processing.

www.robustao.de

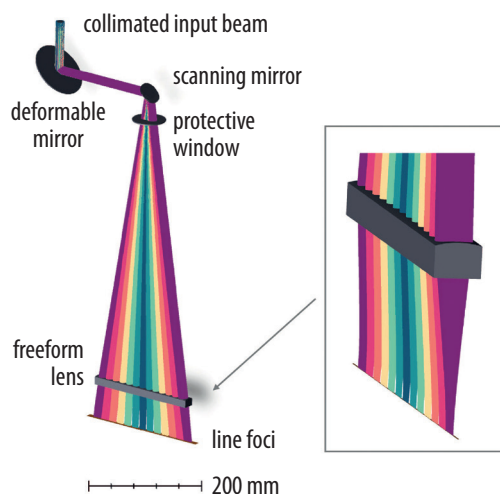


Fig. 3 system layout (Source: Asphericon)

that only small masses are moved, and the achievable speeds are enormous. An absolute measuring sensor was integrated because piezoelectric actuators exhibit hysteresis and nonlinearities. The advantage of the sensor is that the position can be reproducibly approached, even after switching on and off. The mirror is designed as a 90° deflection mirror, which means that the mirror shape must deform biconically in order to prevent astigmatic aberrations when focusing. The mirror membrane has an application-adapted coating. The selected coating peaks reflectivity between 340 nm and 360 nm at over 99.9 %. Furthermore, there is only a minimal difference between the polarization directions. This coating maximizes the reflection of the processing laser so that no losses are caused by the optical system.

Aberrations on the mirror (errors in optical quality) are doubled into wavefront aberrations due to the reflection on the deformable mirror. Aberrations reduce the ability to focus the laser beam and the size of the spots increases, which is more critical for UV applications. Deformable mirrors with thin mirror membranes are particularly susceptible to aberrations. The mirror used has only one actuator for a particularly simple design, so that generated aberrations

cannot be actively compensated. Aberrations must be avoided for the entire adjustment range, in particular for focus-shifting mirrors without an additional process sensor, which analyses the focused laser spot for example. It would therefore make sense to work with small laser apertures. In contrast, particularly small linewidths should be generated for the application, which is why large apertures are favored. As part of the preliminary investigations, an aperture of 10 mm was chosen.

The designed mirror was manufactured, UV-coated and its optical capability then characterized. For this purpose, two optical setups were used that measure at 355 nm – a wavefront measurement setup and an M^2 -setup. The wavefront measuring setup has a collimated laser that is reflected by the Zwobbel mirror and falls on an afocal SID4 sensor (Phasics-SID4-1152c). This experimental setup can be used to evaluate round apertures of 7 mm. As the deformable mirror is a 90° deflecting mirror, an elliptical surface of $7.0 \text{ mm} \times 9.8 \text{ mm}$ is measured on the mirror. The sensor calculates the Strehl and the curvature (ROC – radius of curvature) of the Zwobbel mirror from the measured phase. The measurement setup was modified for the M^2 measurements: a different collimator was used, which

increased the beam diameter to 15 mm. Also, an M^2 sensor (Dataray, device DAT-WinCamD-XHR) was used at a distance of 150 mm with a focusing lens $f = 125 \text{ mm}$.

As a result, an excellent spot quality with ellipticities of $94 \pm 11 \%$ and an astigmatic difference of less than 10% was achieved over the targeted adjustment range of the UV-coated deformable mirror. These optical quality results are consistent with the values obtained with the wavefront sensor. Here, the Strehl was evaluated as a measure of optical quality with $S > 0.83 \pm 0.07$. This is sufficient for the application envisaged in the project.

The Zwobbel mirror is used to refocus the lines with the deflection of the tip/tilt mirror. Fig. 6 shows the required activation of the mirror over the optical scan. Motivated by the need for a processing time of one wafer per minute, the scan time per line needs to be reduced as much as possible. The Zwobbel deformable mirror therefore needs to swiftly refocus along the scanner deflection. Our optical design features small tip/tilt scan angles of 9° and is therefore suitable for galvoscanners. These scanners use skywriting capabilities to maintain precision and a constant speed while deflecting, but skywriting increases the scan time because

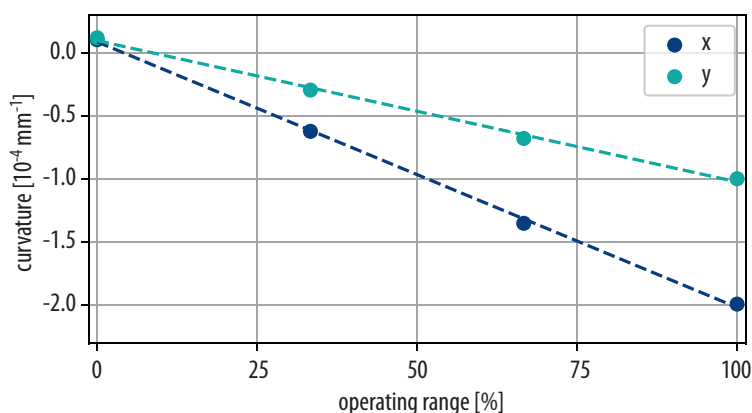


Fig. 4 curvature of deformable mirror along the short and long axis (x and y, respectively) across the operating range (Source: Asphericon)

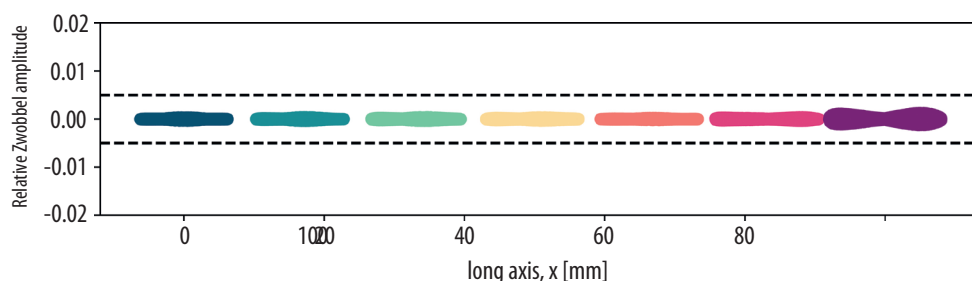
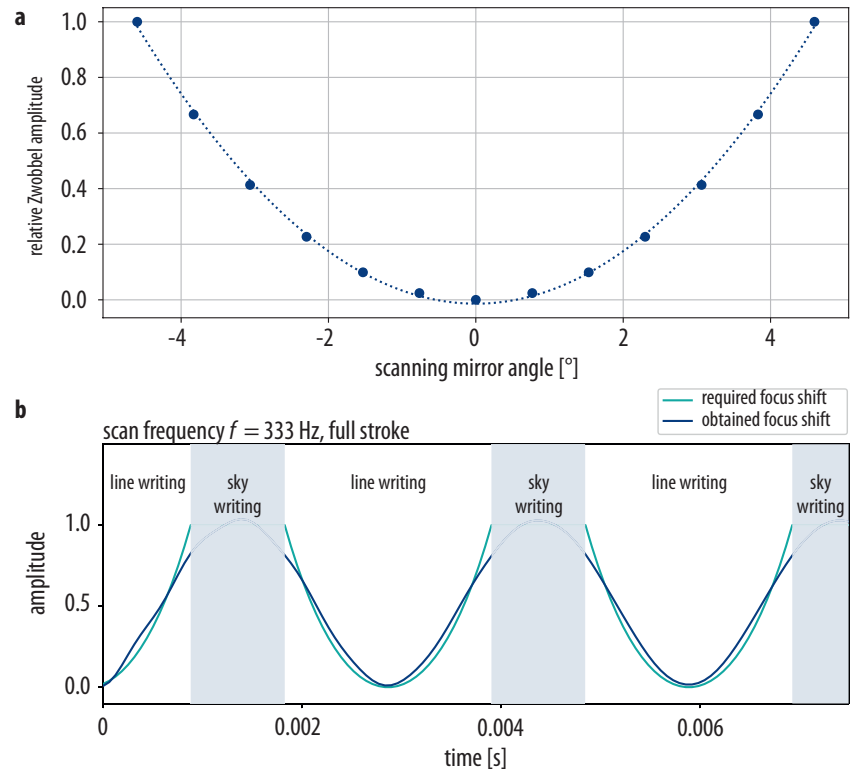


Fig. 5 spot diagrams of the line scanner. Colors refer to different scan angles, as in Fig. 3. Dashed horizontal lines indicate $10 \mu\text{m}$ line width

Fig. 6 (a) required focusing depending on the scan deflection, (b) setpoint (blue) signal along 2.1 ms with 0.9 ms pause. The deformable mirror deflection (red) gives minimum deviation from that target signal.



it is dead time. As lateral scanners are not our focus, we assume that we allocate 2.1 ms for refocusing and 0.9 ms for skywriting between two line scans. This results in a line writing capability of 333 lines per second, where lines are to be written back and forth. As the wafer is moving underneath, 333 lines are equally spread on the wafer. Our measurements (Fig. 6b) show an excellent overlap between the target signal and Zwobbel movement. From that, a mean deviation of 6.9 % during the 2.1 ms writing time is calculated. The maximum deviation of 19.0 % occurs mainly at the largest scan deflection where the signal is discontinuous.

However, further optimization will be possible depending on the scanner setup and the experimental structuring results.

Laboratory integration of the optical design into a mechanical setup

The experiments were carried out at 1,064 nm due to the unavailability of a UV laser source. The optomechanical setup was designed using mainly turnkey off-the-shelf modules to achieve the lowest alignment effort and to facilitate prototyping. Doing this stimulated the application of a commercial fiber collimation solution

(AspheriColl) and beam expanders for beam size adaption. These components are connected to each other via threads and then screwed into the off-the-shelf Zwobbel DBS stage. This forms the body onto which the Zwobbel-1020 focusing device and a dynamic tip/tilt solution may be integrated. A platform scanner with electromagnetic actuators (Cyclops) was selected because of its compactness and the possibility to easily apply UV-coated glass substrates. The freeform lens for generating the line focus is attached to the output of this stage. The distance from the wafer is small as its focal length is $f = 85$ mm.

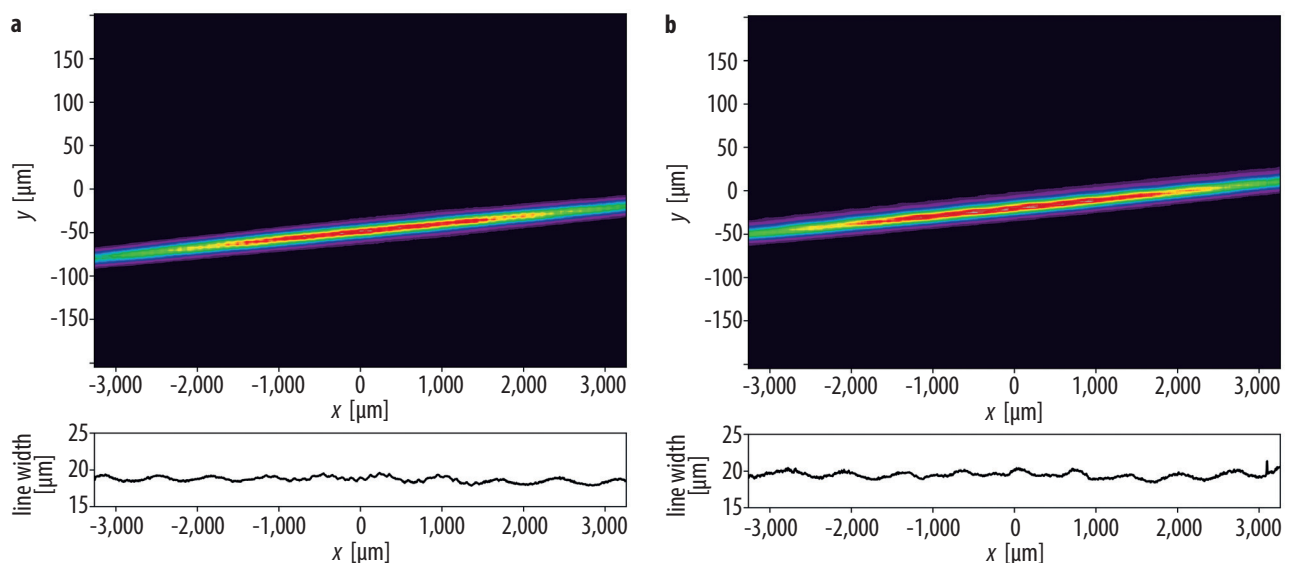


Fig. 7 Measured line focus (a) at maximum field position, (b) in central field position (Source: Asphericon)

The alignment effort of the setup is reduced to six degrees of freedom (DOF) solely at the freeform optic. All other components are integrated via tolerancing. The alignment DOF at the freeform lens was kept on purpose in order to evaluate its suitability to planned industrial applications. The resulting test system is compact (350 mm × 150 mm × 550 mm) and a camera (Dataray, device DAT-WinCamD-XHR) was added to evaluate the line characteristics.

First experimental results

We captured the different line foci using a camera at various angles and field positions to thoroughly analyze the system's performance. By doing so, we confirmed that the line foci meet the IR-equivalent specifications across all tested scenarios. The images clearly demonstrate consistent focus quality and sharpness, even as the angle and field positions change. This comprehensive validation process ensures that the optical system performs reliably under the varying conditions encountered during laser processing, proving it meets the demanding requirements for precision and efficiency in applications like laser contact opening (LCO).

The system's optical parameters were as follows: a focal length of 60 mm for the freeform lens, test wavelength of 1,024 nm, an input beam diameter of 10 mm $1/e^2$, and a scan field of 60 mm. While the diffraction-limited line width

was calculated to be 16 μm $1/e^2$, the achieved line width ranged between 18 μm and 21 μm $1/e^2$.

The transferability of the system to 343 nm wavelength is assured, as the underlying principle remains consistent. The quality of the line focus is predominantly determined by the surface quality of the freeform lens, ensuring that with high manufacturing standards, the system will maintain its precision and reliability across different wavelengths.

Summary and outlook

In our recent project, we developed an advanced optical system for laser processing that addresses the challenges of achieving precise line foci for fast scanning applications. Utilizing freeform lenses and deformable mirrors, our system is designed to handle varying beam angles and field positions effectively. We have validated the system by capturing line foci with a camera at different angles and field positions, confirming that it meets the stringent requirements for sharpness and precision. This validation extends to 343 nm wavelength applications, where the system's performance remains consistent, as the key factor is the high surface quality of the freeform lens.

Looking forward, our technology is well positioned to support roll-to-roll processing methods. By enabling high-speed, high-precision laser processing, the system can efficiently handle con-

tinuous production lines, making it a valuable asset for large-scale manufacturing environments at various wavelengths, starting at the new emerging 2 μm and going all the way down to UV. This advancement not only enhances production efficiency but also contributes to the broader adoption of cutting-edge technologies in the solar industry and beyond.

*

The work presented was conducted as part of the ongoing MIRACLE research project, founded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK).

DOI: 10.1002/phvs.202400035

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Authors

Henrike Schlutow

is head of the optical design team at Asphericon. She joined the company in 2019 and has a particular interest in beam shaping and how it is affected by manufacturing tolerances. Henrike studied physics in Konstanz and Rostock and received her PhD from LMU Munich.



Ulrike Fuchs is vice president of strategy and innovation at Asphericon, overseeing R&D and strategic product development. Since joining

in 2010, she has focused on linking aspherics manufacturing, metrology, and optical design, with a recent emphasis on freeform optics. She is also director-at-large for Optica (2023 – 2025). Ulrike holds a PhD in physics, has authored 70+ publications, registered six patents, and supervised more than twenty theses in optics.



Claudia Reinlein

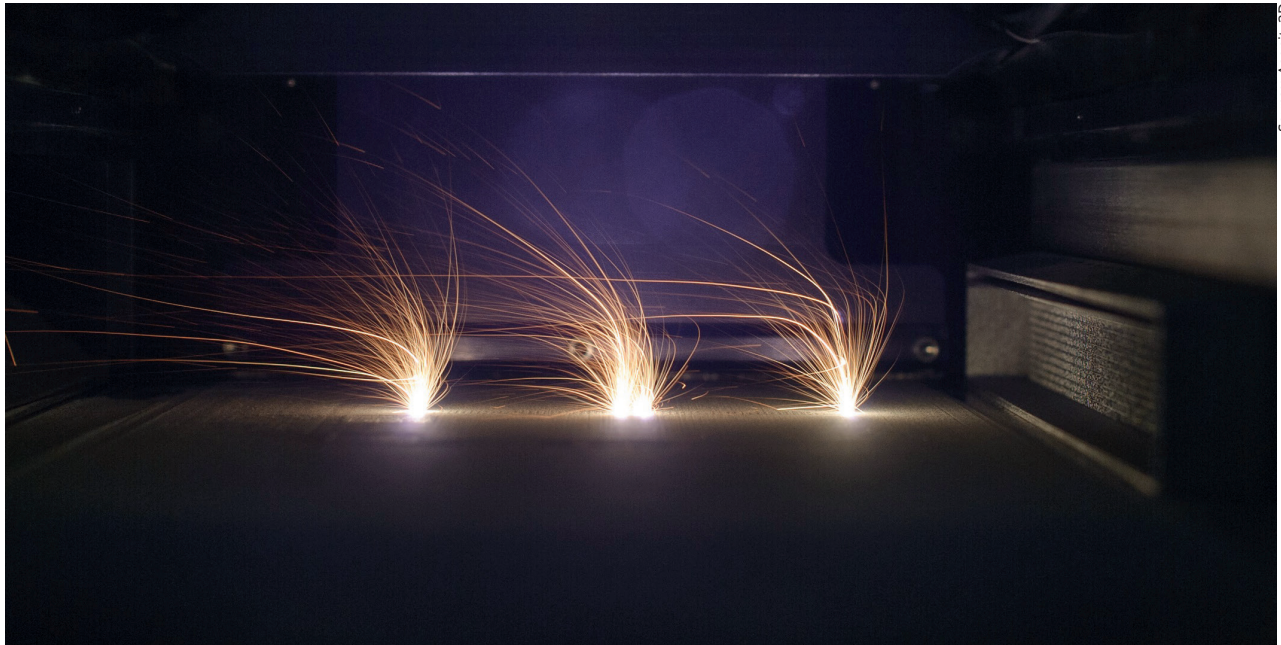
is the CEO of Robust AO, which she founded in September 2020 as a Fraunhofer IOF spin-off. She won the Ostdeutschen Wirtschaftsforums Award in 2023 and the ThEx Award in 2021. Claudia previously led a successful team at Fraunhofer IOF, focusing on active and adaptive optics. She earned her PhD in mechanical engineering from TU Ilmenau in 2012, with award-winning research on printed deformable mirrors.



Dr. Henrike Schlutow, Dr. Ulrike Fuchs, asphericon GmbH, Stockholmer Str. 9, 07747 Jena, Germany; phone: +49 3641 3100-500; e-mail: h.schlutow@asphericon.com, Web: www.asphericon.com, <https://www.linkedin.com/in/ulrike-fuchs-62571884/> ■ Dr. Claudia Reinlein, ROBUST AO GmbH, Hans-Knöll-Straße 6, 07745 Jena, Germany; phone: +49 3641 5541-81; e-mail: claudia.reinlein@robustao.de, Web: <https://robustao.de>, <https://www.linkedin.com/in/claudia-reinlein-5b0288bb/>

Optimized powder bed laser melting processes

Stable processes are a challenge – machine vision provides insights and enables better control



Source: Aconity3D

The goal of Aconity3D is to optimize the stability of an innovative manufacturing method called powder bed laser melting and to promote its use in a wide range of industries. By utilizing high-speed industrial cameras from SVS-Vistek, the company has come one step closer to this goal.

Compared to other production technologies, additive manufacturing is a relatively young discipline. On the one hand it opens up many new possibilities, but on the other hand some aspects have not yet been fully researched and it presents various challenges with a high potential for optimization.

This also applies to powder bed laser melting (PBLM). In this process, the material to be processed is selectively melted layer-by-layer in the form of a powder bed to produce the desired workpieces from 3D model data. The energy required for this is selectively introduced into the process zone using laser beam sources, which melt the powder material in the area of the resulting part. During the subsequent cooling process, the material hardens and forms the desired parts.

This technology is used in the automotive, medical and aerospace

industries, among others, where it is increasingly establishing itself in series production. The main reasons for this positive development are the significantly higher versatility in the design of the manufactured parts compared to many other manufacturing methods, a constantly increasing variety of materials, and falling production costs.

The challenge of stable processes

One challenge to general industrial implementation of the process is stability. The main problem with PBLM compared to conventional methods is that the manufactured part can only be checked for defects once it is unpacked from the surrounding powder material at the end of the process. If there are defects at this stage, they are generally almost impossible to rectify.

▲ Various disruptive phenomena such as melt pool turbulence, welding fume formation, spatter, or other anomalies, make it difficult to monitor and control PBLM processes.

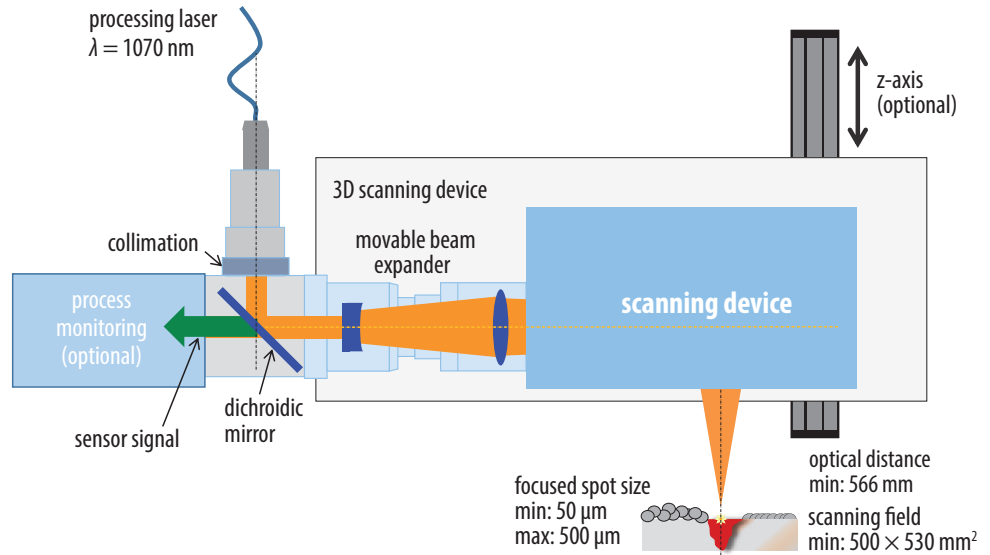
Aconity3D, based in Herzogenrath near Aachen, has set itself the goal of optimizing the stability of metal-based PBLM processes in order to further improve the quality of this technology and promote its use in a wide range of industries. “Process monitoring in PBLM systems is not yet fully developed to the current state of the art,” says Lutz Lübbert, the project manager for machine development at Aconity3D. “In order to change this situation, we have developed a process in which the data from a high-speed machine vision system helps to record the influence of selected process parameters on pro-

duced parts and enable conclusions to be drawn about parameter influences.”

Aconity3D opted for the Mikrotron EoSens3.0MCX5 high-speed camera from SVS-Vistek and the necessary peripherals for this task to implement a system suitable for daily use. According to Lübbert, the reason for this decision was very simple: “When we started researching the market for suitable cameras with the required speed and accuracy for this application around six years ago, there were no comparable cameras available. We have never regretted our decision to use the Mikrotron EoSens3.0MCX5, as the method developed with it has been absolutely stable since its introduction and provides an insight into the correlation of sensor data, the applied process parameters, and the resulting component properties.”

Greater insights with machine vision

The image data provided by the Mikrotron EoSens3.0MCX5 cameras gives the experts at Aconity3D additional insights into the PBLM process, explains Lübbert: “With these high-speed cameras we can compare contour scans of material layers across the build process and observe the behavior of the melt pool in critical areas of the part. This allows us to reliably identify defects such as melt pools breaking off or inhomogeneous surface conditions. The effect on the size of the melt pool of changing laser parameters such as the modulation frequency and modulation length can be seen if all other laser parameters remain constant. The data obtained in this way can be used to expand our knowledge of PBLM



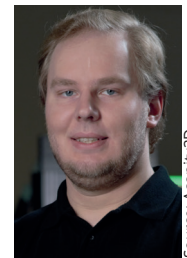
Optical setup of an Aconity3D machine with two high-speed pyrometers and a high-speed CMOS camera (Source: Aconity3D)

processes and to isolate the underlying effects.” According to Lübbert, the knowledge gained this way, in combination with other measurement methods such as pyrometry, forms the basis for

an early stage. This results in a reduced number of destructive material tests and lower manufacturing costs. In addition, reliable process monitoring with a conclusive correlation between the process

“Process monitoring using high-speed vision systems is an effective tool in PBLM processes to improve the quality of parts during production.”

Lutz Lübbert, Aconity3D



Source: Aconity3D

more efficient materials research in the field of 3D metal printing.

Compared to conventional production methods that often rely on the density of the cast semi-finished products, this inline inspection method has the potential to detect production defects at

parameters used and the resulting part properties is a prerequisite for closed-loop process control. Such control systems have been used for conventional laser welding processes for many years. “In PBLM processes, however, process monitoring or even process control is

Companies

SVS-Vistek / Mikrotron

As an innovative manufacturer of high-quality industrial cameras, SVS-Vistek has more than 35 years of exceptional expertise in industrial machine vision. The company develops and produces a wide range of standard cameras as well as cameras with the highest resolutions and speeds, above-average image quality and all relevant interfaces. The former Mikrotron GmbH has been part of SVS-Vistek since 2022 and continues in this constellation to focus on the development, production and distribution of high-speed cameras and high-speed recording systems for a wide range of applications. With high-performance components such as lenses, lighting, filters, frame grabbers, and cables, SVS-Vistek supports its customers in the realization of cost-effective, individual solutions for a wide range of industries.

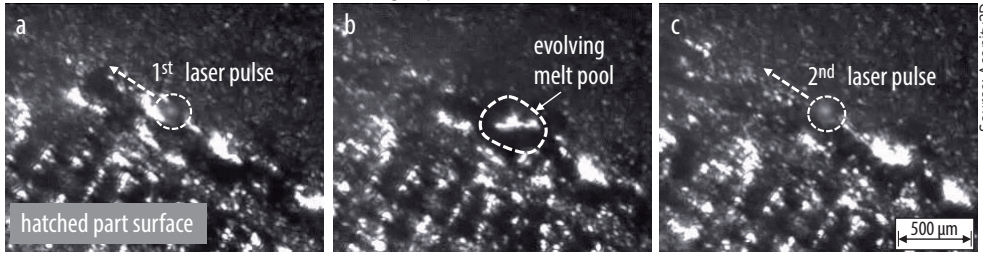
www.svs-vistek.com

Aconity3D

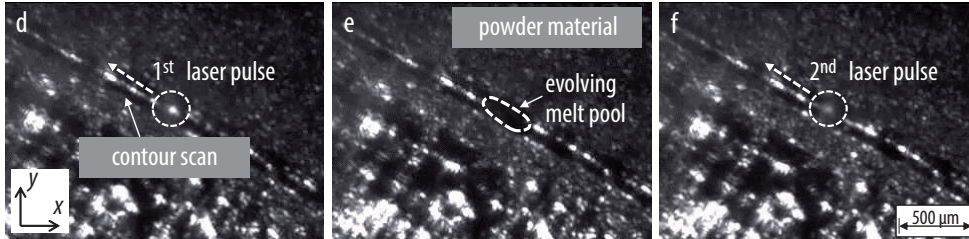
Founded in 2014, Aconity3D is based in Herzogenrath, Germany. The company specializes in the design and sale of modular laboratory systems for powder bed 3D laser printing of metals. With the aim of expanding the range of applications for this innovative manufacturing technology, the freely configurable Aconity3D systems combine maximum functionality with an attractive price structure. Application-specific consulting services, workshops, feasibility studies and the contract manufacturing of components on the company's own systems complement the Aconity3D hardware portfolio to form a holistic implementation concept and open up broad access to this technology. Powder bed 3D laser printing is then within the reach of small and medium-sized companies.

www.aconity3d.com

Laser modulation: $f = 200$ Hz; modulation length: $p = 5$ ms



Laser modulation: $f = 500$ Hz; modulation length: $p = 0.5$ ms



The high resolution and speed of the Mikrottron EoSens3.0MCX5 cameras from SVS-Vistek enable the precise examination of the development of the melt pool and the influence of parameter changes during a part build.

still at a very early technological stage, but our developments are helping to reduce this deficit,” says Lübbert.

The main obstacle to inline process monitoring and control of PBLM processes is the transient nature of the process, which is determined by a variety of different phenomena such as the melt pool turbulence, welding fume formation, spatter, or other anomalies in the powder bed. These underlying disturbing process phenomena increase the measurement noise and reduce the accuracy of the information that can be obtained directly from the melt pool.

Versatile adaptation

The Mikrottron EoSens3.0MCX5 high-speed camera used here is the ideal choice for this application for several reasons, explains Karl Laderer, area sales manager DACH and responsible for sales of the Mikrottron product range. “This high-speed camera uses a sensor where the region of interest (ROI) can be scaled in both the y-direction and the x-direction. The special feature of this sensor is that the frame rate can be increased

by reducing the number of pixels in the x-direction. In this way, small ROIs with a high frame rate can be defined, which gives users in every field of application enormous flexibility to adapt the camera precisely to the requirements at hand.” According to Laderer, the pixel size of $8 \mu\text{m} \times 8 \mu\text{m}$ of the 3 MP sensor and the fanless design for easy integration

the running mechanisms and to improve the quality of parts during production, rather than analyzing the finished parts for subsequent parameter optimization. Our aim is to drive forward the development of detection algorithms that can quickly and reliably identify excessive melt pool sizes in order to initiate immediate countermeasures.



The Mikrottron EoSens3.0MCX5 high-speed camera is the ideal choice to monitor PBLM processes due to its flexibility in ROI and frame rate, among other things.”

Karl Laderer, SVS-Vistek



Source: SVS-Vistek

are also important camera features that ensure reliable results when monitoring PBLM processes. For economic reasons, Aconity3D opted for a camera model with a CXP6 interface, which is less expensive than CXP12 products in this series, but still handles the data streams without any problems.

Optimistic about the future

The inline process monitoring tool developed by Aconity3D is available for almost all of the company’s systems, such as the entry-level system Aconity-MINI and the currently largest system AconityTWO with its optional multilaser setup. According to Lübbert, the target group for these systems are research institutions in Germany and abroad, as well as the research departments of large companies that deal with PBLM processes. “We believe that process monitoring using high-speed vision systems is an effective tool to learn more about

Based on our good experience with the products we have used so far and the helpful support from our machine vision partner, including for programming issues, I see the high-speed cameras from SVS-Vistek as essential components for our future systems.”

SVS-Vistek GmbH

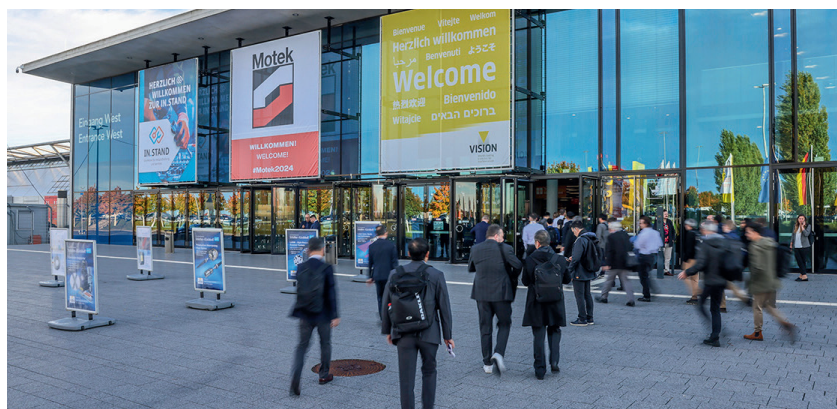
Karl Laderer
Area Sales Manager DACH
Ferdinand-Porsche-Str. 3
82205 Gilching, Germany
phone: +49 8105 398760
fax: +49 8105 3987699
e-mail: info@svs-vistek.com
Web: www.svs-vistek.com

Aconity3D GmbH

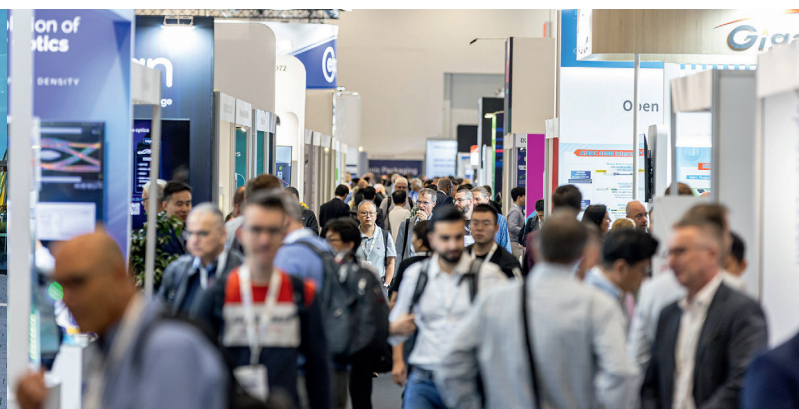
Lutz Lübbert
Project Manager Machine Development
An den Glaswerken 2
52134 Herzogenrath, Germany
phone: +49 2406 927490
fax: +49 2406 9274999
e-mail: info@aconity3d.com
Web: www.aconity3d.com



Aconity3D relies on Mikrottron EoSens3.0MCX5 cameras for its PBLM process analyses (Source: SVS-Vistek)



Source: Landesmesse Stuttgart



Source: Nexus Media

November 06 – 07, 2024**14th Jena Laser Conference**

Jena, Germany

<https://lasertagung-jena.de>**February 22 – 24, 2025****PHOTOPTICS**

Porto, Portugal

<https://photonics.scitevents.org>**November 11 – 14, 2024****Compamed / MEDICA**

Düsseldorf, Germany

www.compamed-tradefair.comwww.medica-tradefair.com**February 25 – 26, 2025****TOP Conference 2025**

London, UK

<https://topconference.com>**November 12 – 15, 2024****electronica & Semicon Europa**

Munich, Germany

<https://electronica.de>www.semicon.europa.org**February 26 – 28, 2025****Asia Photonics Show (APE)**

Singapore

www.asiaphotonicsexpo.com**November 19 – 22, 2024****formnext**

Frankfurt, Germany

<https://formnext.mesago.com>**March 11 – 13, 2025****LASER World of PHOTONICS CHINA**

Shanghai, China

www.world-of-photonics-china.com.cn**November 27 – 28, 2024****13. Laser Anwender Forum | LAF 2024**

Bremen, Germany

www.bias.de/LAF**March 26 – 27, 2025****W3+ Fair**

Wetzlar, Germany

<https://w3-fair.com>**March 31 – April 04, 2025****Hannover Messe**

Hanover, Germany

www.hannovermesse.de**January 25 – 30, 2024****SPIE Photonics West**

San Francisco, CA, USA

<https://spie.org/pw>Read event previews and reviews on www.wileyindustrynews.com/en/events

The optics and photonics community met in Naples

Review: EOSAM, 9 – 13 September 2024, Naples, Italy



EOSAM included high-level presentations on the current and momentous research by seven plenary speakers

The annual flagship event of the European Optical Society EOS is structured to present research results and facilitate their application, to support educational activities, to bridge the gap between industry and academia, and to bring together top researchers, key leaders, students, and industry experts.

EOSAM travels across Europe, this year landing in the sunny and captivating city of Naples. The meeting was

hosted at the facilities of CESTEV, University of Naples Federico II, in close collaboration with the Italian Society for Optics and Photonics, SIOF, the Italian branch of EOS. EOSAM attracted 470 top researchers, key leaders, students, and industry experts from more than thirty countries from all over the globe.

Covering a wide range of topics in optics and photonics, EOSAM 2024 included over four hundred presentations in parallel and plenary sessions. The plenary speakers included outstanding experts such as Hatice Altug, Anna Peacock, Claudio Conti, Miles Padgett, Fredrik Laurell, Kishan Dholaria, and Chi-Kuang Sun.

As part of the EU project sessions organized in collaboration again with Photonics 21, Werner Steinhögl from the European Commission gave an insightful presentation on perspectives for photonics in the context of the PPP and the Chips Act.

The industrial optics podium gave a nice array of points of view on strategies for successful technology transfer from the lab to the market. From the discussion, it is clear there is still work to be done to connect the industry and academia. EOS organized the session for the third time together with EPIC, the European Photonics Industry Consortium.

EOSAM also included twelve tutorial speakers, several special sessions, networking events, and presentations from EOS partners across the globe about their activities, as well as award ceremonies with several new EOS members receiving a distinction for their immense support and contributions to the field of optics and photonics.

The next EOSAM will be held in Delft, the Netherlands, 24 – 28 August 2025.

www.europeanoptics.org

"Shining photonics future with innovations"

Review: 25th China International Optoelectronic Exposition (CIOE 2024), 11 – 13 September 2024, Shenzhen, China



CIOE 2024 concluded with a resounding success at the Shenzhen World Convention and Exhibition Center. As a premier event that encompasses the entire optoelectronics industry chain, CIOE has witnessed the rapid progress of optoelectronic technology and the profound transformation of the industry landscape over the past 25 years. From its humble beginnings as a small-scale exhibition to its current stature as an international event spanning 240,000 square meters, CIOE has grown in scale and influence, fostering technological innovation and industrial upgrading.

It has become a world-leading event that covers the entire industry chain, striving to build a holistic platform for technological innovation, academic discourse, market development, and global collaboration.

Marking its silver jubilee, it attracted over 3,700 high-quality exhibitors from more than thirty countries and regions, showcasing the full spectrum of the optoelectronic industry chain – from chips and devices to full system solutions and manufacturing equipment. Attendees explored the latest technologies in optical communication, optics, lasers, infrared, sensing, and displays. International pavilions from countries like the United States, Canada, Japan, South Korea, Germany, Denmark, and Switzerland presented their latest achievements and innovative products, promoting international technical exchanges and cooperation.

"Intelligent manufacturing with photonics" is a leading technology that drives the development of new produc-

tive forces with its unique advantages and diverse applications. At CIOE 2024, key exhibits included optical processing and coating equipment, camera AA equipment, laser equipment, semiconductor equipment, industrial automation, and testing instruments. These innovations enhance production efficiency and quality stability for core products like optoelectronic chips and optical lenses, while also expanding applications into smart manufacturing, consumer electronics, new energy vehicles, and semiconductors.

Over the three-day event, we welcomed 121,458 professionals from advanced manufacturing, consumer electronics, semiconductors, medical, and security sectors, including 5,018 from overseas, marking a 12.4 % increase from last year. CIOE 2024 was a platform for networking, trendspotting, and technological progress. This cross-industry communication will invigorate the ongoing innovation and growth in the photonics sector.

<https://cioe.cn>

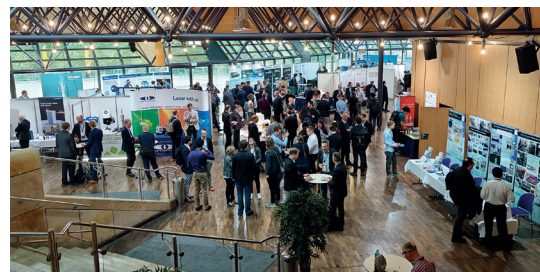
30 years of exchange on laser technology

Review: 13th CIRP Conference [LANE 2024], 15 – 19 September 2024, Fürth, Germany

LANE has its focus on the exchange of up-to-date scientific results and developments on the application of lasers in research and production. This year, about 200 talks – including top-class keynote and inspiring invited presentations – were given and discussed among the participants from science and industry. For the first time, LANE had a joint session with the AITEM LaserEMobility community on “Laser Processes for Future Mobility”. The traditional ‘Country Special’ in the closing plenary session focused on laser tech-

nology in Singapore. The conference program was framed by ceremonies for the WLT Award on the first day and the Best Presentation Award on the last day.

The various events, from the ‘Photonics Casino Night’ at the casual reception, the ‘Keep Lasers Running’ early morning sports program, the conference banquet with the ennoblement of the new Knight of Laser Technology, Prof David Bourell, to the lab tour and cocktail session at the organizers’ laser labs in Erlangen, all worked well for networking in a relaxed atmosphere.



Source: BLZ, H.-J. Krauß

The 14th CIRP Conference on Photonic Technologies [LANE 2026] will take place in Fürth, Germany, from 6 – 10, September 2026.

www.lane-conference.org

Successful networking fair strengthens Central Germany's position as an innovation hub

Review: W3+ Fair Jena 2024, 25 – 26 September 2024, Jena, Germany

The second W3+ Fair in the optics region of Jena, Germany, once again proved to be a magnet for the high-tech sectors of photonics, optics, electronics, mechanics, and related fields. One of the largest technology events in Thuringia, the two-day trade fair was once again a meeting place for experts from key industries. Over 200 exhibitors and partners from eleven nations, including the Netherlands, Switzerland and the USA, presented their high-tech products and services. The number of trade visitors grew by around 15 % to over 2,300.

Many major technology players such as Jenoptik, Schott, Zeiss, Opto-

Tech and the Fraunhofer Institute, as well as numerous niche providers, used the platform to present the latest technological developments and make new business contacts. In the Campus Area, the Ernst Abbe University of Applied Sciences presented the results of its university research in order to ensure an improved transfer to industry.

The composition of the exhibitors confirms that the W3+ Fair has grown beyond a regional event: around thirty percent of the exhibitors came from the Jena/Thuringia region, fifty percent from other German states and twenty percent from other countries, mostly in Europe.



Source: Fleet Events

The next edition of the W3+ Fair in Jena will take place on September 24 & 25, 2025. On March 19 & 20, 2025, the W3+ Fair will take place in Wetzlar.

<https://w3-fair.com/en/jena>

Growth despite negative market conditions

Review: VISION, 8 – 10 October 2024, Stuttgart, Germany

Vision 2024 has once again demonstrated its importance as the leading global trade fair for image processing. Despite challenging market conditions, the trade fair recorded impressive growth: the number of exhibitors rose to 483 companies from 38 countries, and the number of visitors grew by 23 % to over 8,000, with 49 % coming from abroad.

The trade fair offered a platform for groundbreaking technologies and

visionary ideas. Companies presented pioneering solutions and discussed industry trends. Florian Niethammer from Messe Stuttgart emphasized that Vision continued its successful course despite difficult market conditions, and valuable leads were generated.

The VDMA, the trade fair's conceptual sponsor, confirmed the positive impulses of Vision 2024. Anne Wendel from VDMA highlighted the key role of image processing in the global



Source: Landesmesse Stuttgart

automation trend and emphasized the potential of new AI technologies.

The fair also set records in terms of exhibition space and the internationality of exhibitors. Visitors from over 65 countries, including many deci-

sion-makers, underlined the global importance of Vision. The quality of the audience was high, with many decision-makers from various industries.

Overall, the outlook for the European machine vision industry remains

positive, with expected market growth and continuous innovation. The next Vision will take place from 6 – 8 October 2026.

www.messe-stuttgart.de/vision

Trade fair confirmed as an international platform

Review: Quantum Effects, 8 – 9 October 2024, Stuttgart, Germany



Source: Landesmesse Stuttgart

Since its inaugural event last year, Quantum Effects has been regarded as the world's leading trade fair and conference with an annual cycle for application-oriented quantum technologies. The second edition of the event once again impressed with a high level: around 2,500 participants (2023: 2,334), found their way to the

Stuttgart exhibition hall to find out about future topics from 85 exhibitors (2023: 75), to establish networks, to discuss projects and to cultivate scientific exchange.

Participants from 27 countries were welcomed, which together accounted for 12 % of foreign participants. According to a representative survey, quantum computers (51 %), and quantum applications (29 %), were the most interesting items on offer, followed by quantum sensors and imaging (26 %), hardware components (23 %), and quantum security / communication (15 %). The lecture program on the three stages in the hall also met with great interest.

In addition to the new focus theme parks on medical technology and AI/high-performance computing, the

highlights of Quantum Effects 2024 included the start-up investment pitches where experienced investors met with visionary start-ups, the Quantum Effects Awards, and the tour offers on quantum technology, which were gladly accepted by the audience. The CEO dinner on Monday evening in the New Palace was also well received, as was the appearance of the trade fair's first partner country, the Netherlands.

There was a positive response from the exhibitors and visitors. Of those surveyed, 93 % expressed an intention to visit again, and a full 95 % want to recommend the trade fair to others.

The next Quantum Effects will take place on 7 and 8 October 2025 at the Messe Stuttgart exhibition center.

www.messe-stuttgart.de/quantum-effects

Preview: Semicon Europa & Electronica 2024

12 – 15 November 2024, Messe München, Munich, Germany

Co-located with Electronica, Semicon Europa, Europe's premier exhibition and conference for the microelectronics supply chain, will feature keynotes from the electronics design and manufacturing ecosystem, academia and governments.

A highlight of the event, the CxO Summit, will bring together visionary leaders from across the value chain to discuss how Europe's microelectronics ecosystem can collaborate to uphold strategic leadership. The Summit will serve as a stage for fostering insightful partnerships on pressing and emerging challenges throughout Semicon Europa. Executives from AMS Osram, Bosch, Comet Group, Inficon, Porsche, Schneider Electric, Siemens, ST Microelectronics, and other leading companies

will share insights on the critical issues shaping the foundation for sustainable exponential growth in the European semiconductor industry.

Semicon Europa 2024 will feature the launch of the III-V Compound Summit that will showcase the critical importance and emerging impact of III-V compound semiconductors in driving the future of electronics.

At Electronica, more than 3,000 exhibitors from all over the world will present their latest products and solutions. The extensive accompanying program includes practice-oriented forums, conferences, and numerous special events. Electronica will create an international dialogue platform that paves the way to the All Electric Society, in which the entire energy requirement

is covered by CO₂-neutrally generated electricity.

Parallel to Electronica, two top international conferences will take place in the ICM (International Congress Center). The Electronica Automotive Conference will bring together specialists and managers from across the supply chain. Keynote speakers include industry leaders such as Peter Schiefer, automotive president of Infineon Technologies, and Gregg Lowe, CEO of Wolfspeed. The Wireless Congress: Systems & Applications will bring together the international wireless community and will focus on the latest developments and practical applications of advanced wireless systems in industry.

<https://electronica.de>
www.semicon.europa.org

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Preview: SPIE Photonics West 2025

25 – 30 January 2025, Moscone Center, San Francisco, California, USA

Registration has opened for SPIE Photonics West 2025. The largest annual conference and exhibition in optics and photonics, Photonics West brings together researchers, innovators, engineers, and business leaders from across the globe for an exciting week of research-sharing, collaboration opportunities, and innovation-inspiring exchanges. This time, the week will include 4,500-plus technical presentations across more than one hundred technical conferences, as well as showcasing more than 1,200 companies in four focused exhibitions.

Networking, new products, and Nobel laureates complement the broad technical program and four exhibitions at the most exciting week in optics and photonics.

SPIE Photonics West has four major application areas: BIOS highlights new research in biophotonics, biomedical optics, and imaging for diagnostics and therapeutics, LASE focuses on the laser industry and its diverse applications, OPTO covers optoelectronics, photonic materials, and optical devices, and Quantum West features quantum 2.0 technologies from quantum sensing and information systems to quantum-enabled materials and devices and quantum biology. Quantum West also includes a business summit highlighting the innovations

that are moving quantum technologies to market.

The BIOS Expo, featuring technologies in biomedical optics and healthcare applications, runs 25 – 26 January. The AR|VR|MR Expo – with a focus on headsets and hardware for XR applications – takes place on 28 – 29 January. The Quantum West Expo, also 28 – 29 January, will showcase the latest quantum-enabled and enabling technologies. The Photonics West Exhibition, running 28 – 30 January, encompasses the latest innovations from laser manufacturers and suppliers as well as other novel optics and photonics devices, components, systems, and services.

Highlighting the latest innovative research breakthroughs in optics and photonics will be dynamic Hot Topics and plenary speakers, with two Nobel laureates, Mouni Bawendi, Massachusetts Institute of Technology, and Eric Cornell, University of Colorado Boulder, presenting. Fellow plenary speakers include Daniel Elson (Imperial College London), Michalina Gora (Wyss Center), Benjamin Miller (University of Rochester Medical Center), Vivek J. Srinivasan (New York University), Kate Grieve (INSERM), Frédéric Leblond (Polytechnic Montréal), Seemantini Nadkarni (Wellman Center for Photomedicine and Harvard Medical School), Paras N. Prasad (Univer-

SPIE. PHOTONICS WEST

SPIE. QUANTUM WEST EXPO
Part of Photonics West

sity at Buffalo), Naomi J. Halas (Rice University), Joanna Depciuch (Institute of Nuclear Physics, Polish Academy of Sciences), Constantin Häfner (Fraunhofer ILT), Aiko Narazaki (National Institute of Advanced Industrial Science and Technology, Japan), Nathalie Picqué (Max Born Institute), Henry Helvajian (The Aerospace Corporation), Paul Corkum (University of Ottawa), Alexander Szameit (University of Rostock), Christine Silberhorn (University of Paderborn), Tara Fortier (NIST), and Andrew Forbes (University of the Witwatersrand).

Registration for Photonics West covers access to the co-located, three-day SPIE AR|VR|MR conference, which focuses on augmented, virtual, and mixed reality and the vital role that optics and photonics play in hardware and headset development.

“Photonics West 2025 is shaping up to be an exciting and inspiring week,” said SPIE senior director of technical programs Marilyn Gorsuch. “As always, it marks the first major community gathering of the year, bringing together a vibrant mix of industry leaders, engineers, and researchers.”

<https://spie.org/pw>

Preview: Asia Photonics Expo 2025

26 – 28 February 2025, Sands Expo and Convention Centre (Marina Bay Sands), Singapore

Organized by Informa Markets, Asia Photonics Expo (APE) is expected to attract 400+ enterprises and more than 5,000 visitors. APE is a holistic photonics platform for branding and business connection, focusing on the latest cutting-edge innovative technologies and the emerging application markets in Asia, aiming to promote the in-depth communication and business collaboration between the photonics upstream and downstream professionals. This influential event covers a wide range of the cutting-edge innovations and solutions in optical communications, optics, semiconductor, lasers, sensing, and dis-

play, serving as a one-stop platform for industry professionals to discover new technologies and products, and to gain insights into market trends.

With an exhibition area of 15,000 square meters, APE 2025 will see an increased level of international participation compared to 2024, with sixteen international pavilions, including eight from outside mainland China. New participation from countries like Thailand, Malaysia, Japan, South Korea, Germany, India, and Vietnam will enhance the diversity of exhibitors, with Southeast Asian and European-American exhibitors expected to

increase by 21 %. This marks a significant boost in APE's global influence and appeal.

During the exhibition, APE will also hold a variety of concurrent events, such as academic conferences and industry forums for future trends, cutting-edge technologies, site tours to research institutes, R&D centers, and local companies, etc. With the rapid growth of the Asian photonics market, APE 2025 is an ideal platform for companies to elevate their brand visibility and explore new business opportunities.

www.asiaphotonicsexpo.com

APE Asia Photonics Expo

Components and accessories

Cooling systems

technotrans

technotrans systems GmbH
Gottlieb-Daimler-Str. 3-9
76532 Baden-Baden
Tel.: +49 7221 9711-0 Fax.: -111
www.technotrans.de
info@technotrans.de

Extraction systems, AIR Purification



Fuchs Umwelttechnik P+V GmbH
Gassenäcker 35-39
89195 Steinberg
Tel.: +49 (0) 7346 / 9614-0
Fax: +49 (0) 7346 / 8422
E-Mail: info@fuchs-umwelttechnik.com
www.fuchs-umwelttechnik.com



TEKA Absaug- und Entsorgungstechnologie GmbH
Millenkamp 9
48653 Coesfeld
Tel.: +49 2541 84 84 1-0
info@teka.eu | www.teka.eu
Social Media: www.teka.eu/socialmedia

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Laserline GmbH
56218 Mülheim-Kärlich
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Bräunleinsberg 10, 91242 Ottensoos
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Nd:YAG lasers, diode-pumped

PHOTON ENERGY GMBH
Bräunleinsberg 10, 91242 Ottensoos
Tel. +49(0)9123-99034-0, Fax. -22
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PHOTON ENERGY GMBH
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Short-pulse lasers

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Laser optics and components

Beam splitters



Optics Balzers AG
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info.mbo@materion.com
www.materion.com/balzersoptics

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Zünd precision Optics Ltd
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Mirror coatings

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info@bm-optik.de / www.bm-optik.de

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info.mbo@materion.com
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Mirros, UV

Optics Balzers AG
Balzers, Liechtenstein
Phone +423 388 92 00
info.mbo@materion.com
www.materion.com/balzersoptics

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B&M Optik GmbH
Am Fleckenberg 20, 65549 Limburg
+49 (0) 6431 9860 – 0
info@bm-optik.de / www.bm-optik.de

Optics Balzers AG
Balzers, Liechtenstein
Phone +423 388 92 00
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www.materion.com/balzersoptics

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+49 (0) 6431 9860 – 0
info@bm-optik.de / www.bm-optik.de

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Balzers, Liechtenstein
Phone +423 388 92 00
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www.materion.com/balzersoptics

Windows, optical

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info@bm-optik.de / www.bm-optik.de

Material processing systems

Laser welding

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www.evossys-laser.com
sales@evossys-laser.com

LPKF WeldingQuipment GmbH
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www.lpkf-laserwelding.de

Marking systems

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Optical components

3D Anti-Glare-Spray



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3D-Laserscanning-Entspiegelungsspray
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Transmission/reflection measurement of thin films



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www.essentoptics.com

Velocity measurement

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info@polytec.de

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OPTICS • PHOTONICS • LASER TECHNOLOGY

Wiley-VCH GmbH
Boschstraße 12, 69469 Weinheim, Germany
ISSN 2626-1294

Editorial:
Dr. Oliver Dreissigacker (od; responsible)
phone: +49 6201 606-181
Boschstr. 12, 69469 Weinheim, Germany
e-mail: photonicsviews@wiley.com
www.photonicsviews.com

Contributing Editors:
Jan Oliver Löffken

Copy editing: Matthias Erler, David Jayne

Subscriptions:
Wiley GIT Reader Service
65341 Eltville, Germany
phone: +49 6123 9238-246
fax: +49 6123 9238-244
e-mail: WileyGIT@vusevice.de
Service available from Monday to Friday 8 am – 5 pm (CEST)

Advertising:
Alexandra Wojtanowska (responsible)
Boschstraße 12, 69469 Weinheim, Germany
phone: +49 6201 606-552
e-mail: awojtanows@wiley.com

Nicole Schramm (Executive)
Boschstraße 12, 69469 Weinheim, Germany
phone: +49 6201 606-559
e-mail: nschramm@wiley.com

Valid advertising price list until 30 September 2025: 01 October 2024

Banking account:
JP Morgan AG, Frankfurt, Germany
Account number: 6161517443
BLZ: 50110800
BIC: CHASDEFX
IBAN: DE555501108006161517443

Production / Layout:
Melanie Brunner-Straub / Andreas Keiner, Gießen

Sales Team Lead: Miryam Reubold
Sales Director: Jörg Wüllner
Publishing Director: Steffen Ebert

Printed in Germany by westermann DRUCK I pva

Per media partnership or publishing co-operation, members of the European Photonics Industry Consortium EPIC, Photonics Germany – through OptecNet Deutschland e.V. and SPECTARIS Deutscher Industrieverband für Optik, Photonik, Analysen- und Medizintechnik e.V. – and European Optical Society (EOS) with its national optical societies, especially the Deutsche Gesellschaft für angewandte Optik DGAO, receive PhotonicsViews with currently five print issues per year.

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19. November 14:00 Uhr – Okadis Consulting GmbH

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20. November 16:00 Uhr – Carl Zeiss AG

21. November 16:00 Uhr – d-fine GmbH