Volume 19 October/November 2022

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PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY

FOCUS
Additive Manufacturing

Technology Report
Lasers in plastic processing, a big impact in the industry

Trends in Manufacturing
Optical metasurfaces made by cell projection lithography

WILEY

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www.epic-assoc.com

Laser-based 3D printing in glass

The new frontier of precision manufacturing for optics and photonics

Laser-based 3D printing in glass has become a mature technology over the last ten years. It is now out of the R&D labs and is deployed in industry as a scalable micromanufacturing process to produce innovative optics and photonics devices. Micro-optics, integrated photonics, optical communication, innovative displays, photonic and quantum computing are among the fields that are looking at laser-based 3D printing in glass as a potentially ground-breaking technology for the precision manufacturing of disruptive miniaturized devices.

In 2013 Femtoprint became the first industrial supplier and a market leader in high-precision, 3D printing of custom-designed glass micro-devices. Our technology is an innovative, micromachining technique based on laser writing and material processing. It is a subtractive and direct-write process able to create advanced 3D microsystems with micrometer precision and excellent repeatability.

From our privileged viewpoint, we see two clear trends that are going to create a major impact in manufacturing and product development: monolithic integration and scalability.

On the one hand, the current miniaturization of photonic systems requires access to advanced microfabrication technologies that are able both to guarantee high resolution and to enable broad, cost-effective deployment while maintaining and possibly increasing the amount and quality of functionalities. The FEMTOPRINT microfabrication platform allows 3D freedom in design and fabrication, as well as the possibility of monolithically integrating several functionalities within a single photonic system, thus avoiding complex assembly steps while still allowing for a high level of complexity.

On the other hand, the photonics industry today requires access to fast prototyping and pilot production capabilities during product development, while guaranteeing the ability to easily up-scale to volume production and effectively support product commercialization. As a high-tech contract development and manufacturing organization, Femtoprint serves leading industrial customers in different fields with feasibility, rapid prototyping, pilot and industrial series manufacturing at wafer level.

In this context, we are committed to bringing laser-based 3D printing in glass to the next level, and setting a new paradigm in the glass micromanufacturing industry.

Sincerely yours,

Nicoletta Casanova

Nicoletta Casanova
CEO Femtoprint
Board member EPIC

PhotonicsViews

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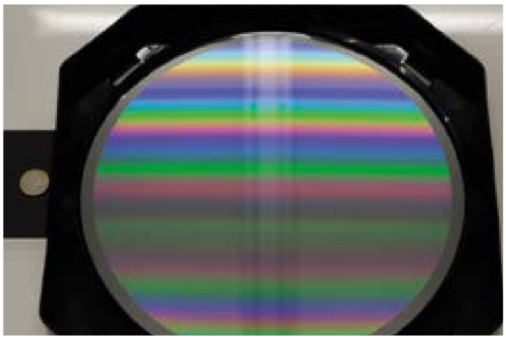

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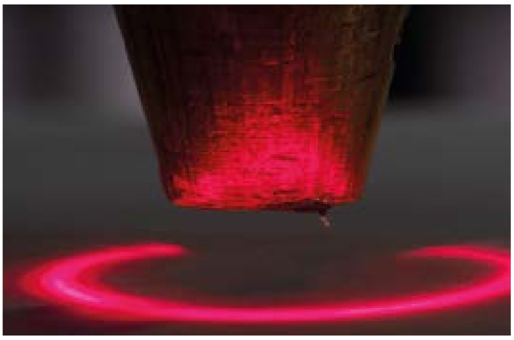
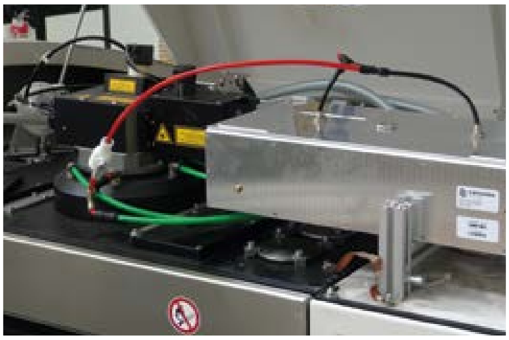
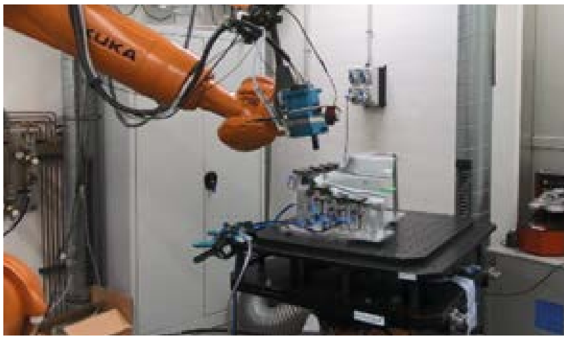






Cover:
Resilient laser cladding with a high-power laser, wire and powder creates efficient, fast, and sustainable coatings for industrial components, developed within project HICLAD.
p. 37

Despite fears, 3D printing has positive effects on global trade

Research from the World Bank and the School of Global Policy and Strategy of the University of California San Diego (UCSD) finds the technology is a boon to trade, allowing participating countries to provide higher income and more opportunities to their people. The paper coauthored by UCSD economist Caroline Freund looks at the production of hearing aids – frequently produced by 3D printing – and found that it changed production processes, but supply chains remained intact. The study is the first to examine the impact 3D printing has on trade. The results reveal that the shift to 3D printing led to a doubling or near doubling in producers' exports after five years and the technology was the main cause for the rise in exports. Freund and coauthors also examined 35 other products, such as running shoes, aircraft parts and prosthetic limbs that are increasingly being 3D printed and they found similar patterns.

Freund said: "A country's exports of hearing aids increased more than trade in other goods following the adoption of 3D printing by manufacturers there. The new production technology in combination with trade means that consumers around the world suffering hearing loss are benefitting from better and often cheaper hearing aids."

One reason behind the expansion is that printing hearing aids in high volumes requires a large investment in technology and machinery. The countries that were early innovators – Denmark, Switzerland and Singapore – dominate exports of these items, while middle-income economies such as China, Mexico and Vietnam have also been able to substantially increase their market shares.

In addition, hearing aids are lightweight products, which makes them fairly cheap to ship internationally. The same is true for the other products the authors examined – lighter products are associated with more trade growth.

These results are based on comparisons of the growth of the 3D printed products to other similar goods. The authors also accounted for trends and other factors that could skew the data.

"Policymakers often view 3D printing as a means to shorten supply chains when in fact it is more likely to enhance trade and reshape supply chains," said Freund, formerly a global director at the World Bank.

While the analysis of 3D printing's impact on trade is positive, the effect may be short-lived. If 3D printers become more accessible to local producers or even consumers in some sectors, production could be more localized, hindering development opportunities through trade.

Reference: *C. Freund, A. Mulabdic, M. Ruta:* Is 3D printing a threat to global trade? The trade effects you didn't hear about, Journal of International Economy **138** (Sept. 2022); DOI: 10.1016/j.jinteco.2022.103646

https://ucsd.edu

VDMA member survey: additive manufacturing business outlook remains good

"Almost three quarters of our member companies expect their business in Germany to grow over the next 24 months," reports Dr Markus Heering, managing director of the additive manufacturing (AM) working group within the VDMA. At the same time, in the current autumn survey among the approximately two hundred members, a full 8 % report declining sales in the last twelve months. "Against the backdrop of the current tense geopolitical situation and the continuing rise in energy and raw material prices, we were pleasantly surprised by the figures," he says.

AM equipment manufacturers and their suppliers are just as strongly represented in the survey as suppliers of materials, software, or consulting as well as research institutes and AM manufacturing service providers. Around three quarters of the members process metals, 53 % plastics, with one third of the members active in both plastics and metal printing.

This broad base of the member survey suggests that the young AM industry as a whole has developed high resilience to the economic disruptions. "With their highly flexible manufacturing processes, short delivery times and superior functionality of AM components of any complex shape, our members find the right answers to the current challenges of their target markets," explains Heering. 27 % of the respondents see mechanical and plant engineering as the most important field of application, closely followed by aerospace and medical technology, each named by 23 %. 8 % each name the automotive and consumer goods sectors as important user industries. This evenly distributed customer structure is joined by another trend that speaks for the increasing maturity of the industry. At 35 %, additively manufactured series components are now almost as relevant to the members as prototypes.

Survey represents entire process chain

The increasing breadth of applications gave almost a quarter of the respondents sales increases of over 20 % last year. For another 52 % of member companies, the increases ranged up to 20 % while 17 % reported unchanged business. In detail, a slightly declining growth trend can be seen in the last half-year: the increases mainly settled in the single-digit percentage range. The trend is confirmed in the short and medium-term expectations in the AM domestic market. In the coming half-year, 48 % expect stagnating business and only 46 % expect growth. The outlook for the next 24 months shows unbroken optimism: a full 74 % of member companies expect growth, only 20 % stagnation and just 6 % expect a decline in market development.

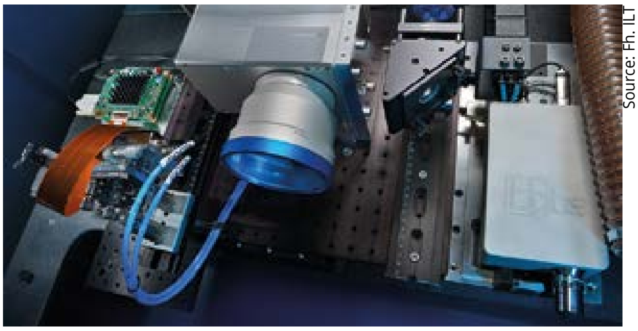
The member companies' export expectations give a similar picture. Short-term optimism has also slowed here. Almost 60 % expect stagnating foreign business in the next twelve months; only 40 % are set on growth. Looking ahead to the next two years, the tide turns: 58 % expect growth; 40 % expect stagnation. Indeed, the mood is slightly gloomier than in the last two surveys in autumn 2021 and spring 2022. "Nevertheless, the overall picture remains positive despite the looming economic crisis," explains Heering. This is also supported by the member companies' continued high willingness to invest and their focus on the development of new products and new markets, from which the majority of respondents expect positive effects for their own business in the coming months.

https://am.vdma.org

Joint Application Lab with Hamamatsu Photonics opened at Fraunhofer ILT

The Fraunhofer Institute for Laser Technology ILT has set up an application lab for advanced laser material processing with ultra-short-pulsed (USP) laser radiation together with Hamamatsu. In Aachen, Germany, the partners jointly developed an industrial processing SLM head that can use customized, dynamic beam shaping combined with large laser average output powers for a wide range of applications.

To increase the economic benefit of USP laser processing, research uses different hardware approaches to address the handling of increased high average laser powers of more than 100 watts, thereby upscaling processing speeds and lower unit costs. One popular method to implement these large laser powers is to split the high-energy radiation in a spatial light modulator (SLM) into many individual beams. This approach is already being used industrially, particularly for two-dimensional laser material processing or for the generation of periodic patterns such as filters.



Source: Fh. ILT

Scanner-based process head with an integrated high-power SLM integrated into a 3-axis machine with a 150 W USP laser.

In the Joint Application Lab, an industry-ready prototype is ready for the development of manufacturing processes. This includes a scanner-based process head into which Hamamatsu's new high-power SLM is integrated.

www.ilt.fraunhofer.de

Instrument Systems acquires Kimsoptec

The Korean manufacturer of display measurement systems has been acquired in full by Instrument Systems, strengthening the core business areas of display testing and optical metrology. The purchase agreement for the acquisition of 100 % of the shares in Kimsoptec Co Ltd was signed on July 26, 2022 (pictured). The Korean company has been the exclusive distributor of the Instrument Systems product portfolio in Korea since 2005 and also produces display measuring instruments itself.

Instrument Systems, a subsidiary of Konica Minolta, produces spectroradiometers, cameras and display and light measurement systems. It is now planning to expand its business with measurement solutions for display,

Source: Instrument Systems

IR radiation sources and AR/VR measurement solutions for the Asian ICT and automotive markets. The company aims to expand these markets by developing more sales channels to existing key accounts and to system integrators in Korea.

www.instrumentsystems.com
www.kimsoptec.com

SVS-Vistek merged with Mikrotron

Retrospectively as of January 1, 2022, SVS-Vistek has acquired all shares in Mikrotron GmbH. The two camera manufacturers both belong to the parent company TKH Vision. The marriage is intended to open up new market segments. The Mikrotron brand remains.

The new setup is intended to create synergies for the development and use of high-end cameras in particular, which stand out from the competition in terms of speed and resolution. All previous Mikrotron employees will find their place within the merged company at the joint location in Gilching. Mikrotron cameras will continue to be further developed,

Source: SVS-Vistek

The headquarters of SVS-Vistek in Bavaria

produced, distributed and supported.

Founded in 1976, Mikrotron is a manufacturer of small and particularly robust high-speed cameras. SVS-Vistek has enabled industrial image processing for 35 years as a manufacturer of industrial cameras and customized system solutions in image processing.

www.svs-vistek.com

Toptica increases capacity for growing workforce

The North American subsidiary Toptica Photonics Inc. near Rochester, NY, has moved from its Ontario County location in Farmington to Pittsford.

The new facility more than doubles the footprint, allowing the company to increase its lab and production spaces that are critical for anticipated growth over the next decade.

At the new location at 1120 Pittsford Victor Road, Toptica will occupy more than two thirds of the space, with options to expand in the future. The building features multiple custom facilities for manufacturing and development, including robust R&D space and multipurpose cleanrooms.

The move is fueled by rapid growth over the past two decades. Since 2006, the company has averaged strong double digit growth year over year. Toptica employs nearly forty people in the Rochester, NY, area and expects the number to increase to about seventy employees over the next few years. Multiple positions are currently open.

"This move signifies a new era for Toptica," said Mark A. Tolbert, president and CEO. "We now have the resources to sustain the incredible growth we have experienced over the last two decades, and

Source: Toptica

New location at 1120 Pittsford Victor Road.

continue our contribution to research and industry in the quantum, biophotonics, and materials markets."

www.toptica.com

IQE and Lumentum sign multiyear agreement

The supplier of compound semiconductor wafer products and advanced material solutions IQE has signed an


Source: IQE

agreement with Lumentum for the supply of epiwafers supporting 3D sensing lidar for automotive and optical networking applications.

Photonics solutions provider Lumentum has been a long-term partner of IQE. Effective immediately, the multiyear agreement is focused on high volume production of epiwafers which will be used across Lumentum's portfolio of innovative laser products, in particular to enable lidar for autonomous vehicles and leadership across a wider range of cutting-edge technologies such as biometric security, data communications, and XR.

www.lumentum.com
www.iqep.com

Synova opens subsidiary in Dubai

In the Almas Tower in Dubai, the leading trading hub for diamonds, Synova recently opened a subsidiary and micromachining center (MMC) . The new DaVinci Lab will play a key role in Synova's growth in the Middle East region and in the diamond industry in particular.


MMC in Dubai, UAE (Source: Synova)

The first 5-axis DaVinci laser diamond-cutting system is already installed and operational. The new diamond center of excellence offers job shop cutting services for rough diamonds ranging from sawing, pie cutting and drilling to faceting and fancy shaping.

DaVinci Diamond Factory is an automated full-faceting solution for round brilliants and fancy shapes where cut-off diamond chips can be reused and are not polished away as in traditional diamond manufacturing.

www.synova.ch

Luxinar celebrates opening of US office

Laser manufacturer Luxinar has opened its US office near Detroit. The team of regional general manager John Podwojski and technical support manager Dan McArthur welcomed guests to the regional

Source: Luxinar

Luxinar USA ribbon-cutting ceremony

office in Shelby Township. CMR directors Christian Zimmer and Dr Ralf Kogeler, owners of Luxinar, officiated the ceremony and managing director Michael Porbadnik, finance director Mitch Mead, global sales and marketing manager Yannick Galais, and global aftersales manager Simon Bateman from the UK were in attendance. Several key US customers, chamber of commerce director Eve O'Connor and Shelby supervisor Rick Stathakis also participated.

www.luxinar.com

Joint competence centers of Isra Vision, Perceptron, and Quiss


Gap and flush measurement with Perceptron technology AutoFit (Source: Isra Vision)

Under the new joint slogan 'envisioning the future', the three companies are offering a comprehensive portfolio of solutions for surface inspection, quality assurance, metrology, machine vision and 3D robotics.

Last year, Isra Vision, the specialist for surface inspection and 3D machine vision, formed its alliance with Perceptron, the provider of automated 3D measurement solutions and coordinate measurement systems, and Quiss, experts for professional image processing and visual quality control. The company has thereby further strengthened its position in the market for industrial image processing under the umbrella of the Atlas Copco Group.

The alliance benefits customers, who receive high-performance solutions for smart factory automation as well as comprehensive support from consulting to commissioning and service – all directly from a single source.

In their respective sectors, Isra Vision, Perceptron, and Quiss have established joint competence centers for the four key areas of surface inspection, quality vision, industrial metrology, and robot vision. These include defining comprehensive solutions and products for the future that will support customers in setting new quality standards in their respective industries.

www.isravision.com
www.perceptron.com
www.quiss.com

Scansonic MI takes over its sales efforts

The provider of laser products in metal processing is now conducting its own worldwide sales efforts itself. The manufacturers of laser processing optics, has therefore reorganized its global sales structure, working with its own branch offices in its key markets of Germany, China, and the USA. Sales activities in the rest of the world are supported by experienced sales partners and distributors. The Scansonic sales team has been significantly expanded and restructured in recent months to support this new arrangement.

These efforts are part of Scansonic's continued growth strategy. The company's products for laser-based metal processing require intensive consultation, and are generally adapted to each customer's individual production processes.

Dr Axel Luft, managing director sales at Scansonic, explains the benefits for customers: "With this new structure, our experienced


Source: Scansonic

Dr Axel Luft

sales force keeps close to our customer base around the world, and also works closely with Scansonic specialists from the product teams and the application laboratories."

Luft expressed the company's thanks to its former sales and service partner, Abicor Binzel, for their many years of collaboration.

www.scansonic.de

Evident to be sold to Bain Capital

Olympus is divesting its Evident subsidiary, which provides scientific and industrial solutions. The buyer is the private equity firm Bain Capital. According to the agreement concluded, all shares in Evident will be transferred to Bain Capital on January 4, 2023.

Olympus spun off the scientifc solutions business unit with the life science and industry application sectors into the independent subsidiary Evident in April 2022. Following the sale of the imaging business, this was a further step towards a pure focus on medical technology. With the sale of Evident, Olympus now intends to expand this business area. The focus is to be on the endoscopic solutions and therapeutic solutions business units.

Yoshitake Saito, president and representative director of Evident, commented on the company's future: "Evident will continue under the umbrella of Bain Capital to offer a wide range of innovative products and services to the company's customers around the world. With greater autonomy at the management level, we are more likely to be able to implement flexible, open innovation to increase the speed of product development, enabling us to find solutions to our customers' challenges faster."

www.evidentscientific.com
www.olympus.com

Precitec expands company headquarters

Source: Precitec

The laying of the foundation stone with representatives of the town, the architects and the company

The laying of the foundation stone for the expansion of Precitec's main site for laser cutting and welding heads in Gaggenau took place on July 25, 2022. The building is scheduled to be ready for occupation in the summer of 2023.

The new two-storey building at Precitec's headquarters in Gaggenau has a total area of 5,000 square meters and will house the entire production of laser cutting and welding heads, a customer center and office space, starting next summer.

The upper floor will house production and logistics. A good part of this, around 1,600 square meters, is intended for cleanroom production, for example of optical systems for laser cutting and welding.

Heat and electricity will be generated in the new building by a photovoltaic system and a combined heat and power plant. The company is also installing charging stations for electric cars.

www.precitec.com

Daimler acquires stake in Manz

Manz supplies essential equipment for the battery pilot line and has become a strategic partner of Daimler Truck. The companies have signed a cooperation agreement on a strategic partnership to establish a pilot line for the production of lithium-ion battery cells and for the assembly of batteries at the truck maker's Mannheim, Germany, site.

Daimler Truck will become a major anchor shareholder in German high-tech engineering company Manz through a capital increase of around ten percent, subject to approval by the relevant antitrust authorities. Within the framework of this partnership, both companies will pool their expertise and develop further projects for their joint future. The aim is to develop innovative battery technology and associated production processes for trucks and buses.

Manz is a globally active high-tech machine manufacturer with a focus on the automotive industry and electromobility. The Reutlingen-based company has more than ten years of process and product experience in plant engineering for cell and battery production. With this investment, Daimler Truck is taking a strategically important step in the design of CO_2-neutral transport and in the transformation from conventional drive systems to alternative drive technologies.

www.manz.com
www.daimlertruck.com

Yaris Pürsün, head of global power systems operation, Daimler Truck (left), Martin Drasch, CEO Manz (Source: Daimler / Manz)

Trumpf partners with the Cellforce Group

The battery manufacturer Cellforce will use Trumpf lasers to produce high-performance lithium-ion cells in Reutlingen.

The high-tech company Trumpf and the manufacturer of high-performance battery cells for electromobility entered into a strategic partnership. "Our goal is to produce one of the most powerful battery cells in the world," says Dr Markus Gräf, COO of Cellforce, a joint venture of Porsche and Customcells. "We will bring our experience in the production of battery cells to this partnership. Cellforce should benefit from our new application solutions at an early stage and can test our latest laser technology," says Trumpf laser technology CEO Dr Christian Schmitz.

Trumpf already supplies laser systems to Cellforce for the production of the high-performance battery cells. These will be used in a pilot plant. "We want to raise the energy density, performance and fast-charging capability of the battery cell to a new level," says Gräf. Cellforce's production facility, which is currently under construction near Reutlingen in southern is scheduled to go into operation in 2024 with an initial capacity of at least 100 MWh per year. That is equivalent to high-performance battery cells for around one thousand vehicles.

Source: Trumpf

Dr Markus Gräf (l.), Dr Christian Schmitz

"The laser is the decisive tool for the efficient production of battery cells, without which e-mobility would really not be possible," says Schmitz. There are currently more than thirty different laser applications in the production of the cells.

www.trumpf.com
www.cellforcegroup.com

Aquitaine's new industrial laser company

Founded in September 2021, following the Alienor collaborative project, the nascent and promising start-up Bloom Lasers has established full operation in Pessac, Cité de la Photonique, in the design of industrial lasers.

Bloom's R&D and application lab resides in the Institut d'optique d'Aquitaine in Talence (Source: Bloom Lasers)

The co-founders team of Bloom Lasers, led by Julien Saby, formerly involved in the Alienor collaborative project, launched the start-up which combines both a unique proficiency in the design and manufacturing of industrial lasers and a mature and reliable technology. In photonics and optical technologies, Bloom already offers two agile UV nanosecond models for laser micromachining: Yucca and Carex.

Bloom will address microelectronics markets driven by future technologies (5G, portable medical devices, electric cars, mobile telephony) as well as the energy sector, such as the manufacturing of batteries and photovoltaic panels.

Alphanov supported the Bloom Lasers team throughout 2020 and 2021 via the Alienor project, funded by the Regional Council of New Aquitaine.

www.alphanov.com
https://bloom-lasers.com

Amcoss increases productivity for Jenoptik

Jenoptik, a manufacturer of high-power, edge-emitting, semiconductor lasers, will use new equipment in its lithography processes. Amcoss, based in Feldkirch, Austria, has supplied a fully automatic amc 2000 wafer processing unit for the coating and developing of wafers in parallel operation of up to four processes.

"Our goal is to significantly increase capacity and yield, compared to the tool we have been using so far, which will noticeably raise productivity. Furthermore, we need optimized wafer centering and more flexible application capability for 3" and 4" wafers. We will reach these goals and increase our quality and efficiency with this machine", says Dr Jürgen Sebastian, site manager of Jenoptik Berlin where high-power diode lasers for medical applications, materials processing, R&D, and as pump sources are being produced.

Source: Jenoptik

The amc 2000 machine at Jenoptik Berlin

Amcoss wafer processing equipment is configured according to individual customer needs and demands. "We do not build mass products, but each of our machines is a highly complex single piece" explains company owner David Erne.

In addition to the new wafer processing tool in Berlin, an amc 2500 unit has been installed at the Jenoptik site in Dresden.

https://amcoss.com
www.jenoptik.de

€ 7 M to deliver truly realistic AR/VR

An investment will accelerate Swave Photonics' development of revolutionary holographic extended reality (HXR) technology to make VR practically indistinguishable from the real world.

Source: imec

l–r: Xavier Rottenberg, fellow sensing and actuation technologies at Imec, Theodore Marescaux, CEO and founder of Swave Photonics, and Olivier Rousseaux, director venturing development at Imec.

A new Imec and Vrije Universiteit Brussel spin-off, Swave Photonics, an innovator in holographic extended reality (HXR) technology to bring the metaverse to life, completed a seven million euro seed round. The investment will be used to fund the commercialization of truly realistic, immersive 3D HXR gigapixel technology for a wide range of emerging applications in the 93 billion dollar AR/VR metaverse market.

Swave Photonics is a fabless semiconductor company that designs and markets holographic chips based on proprietary diffractive photonics technology. Swave's HXR technology projects lifelike holographic images that eliminate today's AR/VR/XR challenges of focal depth and eye tracking, so viewers can easily focus on nearby and faraway objects. Most importantly, the HXR chips are manufactured using standard CMOS technology, which enables cost-effective scaling.

Participating investors in the initial seed round include Imec.xpand, Flanders Future Techfund (FFTF), and QBIC.

www.imec-int.com

Partnership for smart glasses of the future

Announcment by Vittorio Colao, Minister for Technological Innovation and Digital Transition; Giuseppe Sala, Mayor of Milan; Fabrizio Sala, Lombardy's regional Minister for Research; Ferruccio Resta, rector of Politecnico di Milano, and Francesco Milleri, chairman and CEO of Essilor-Luxottica. (Source: PoliMi)

Essilor-Luxottica and the Politecnico di Milano have created the first ever joint research center aimed at designing the smart glasses of the future, Essilor-Luxottica Smart Eyewear Lab.

The project will encompass industrial research and experimental development of devices underlying a new generation of wearables that are capable of autonomous network connection. The Essilor-Luxottica Smart Eyewear Lab will initially last five years and, when fully operational, will employ over one hundred researchers working in a dedicated space within the Innovation District, which Politecnico di Milano is currently developing in the Parco dei Gasometri, located in the Bovisa area in Milan.

www.essilorluxottica.com
www.polimi.it

Edmund Optics appoints new CEO, board chair, SVP corporate development

Samuel Sadoulet

Marisa Edmund

James Fisher

Source all images: Edmund Optics

EO announces the retirement of Robert Edmund and the appointment of Marisa Edmund as chair of the board of directors. Marisa Edmund and the board of directors have appointed Samuel Sadoulet as chief executive officer.

Sadoulet has 25 years of management and engineering experience at EO, with a professional background in physics and optical sciences. In addition to his strong expertise, he has held multiple operational roles and helped build EO's reputation as a leader in customer service and engineering solutions, most recently as president and chief operating officer. Sam received his bachelor's degree in physics from the University of Rochester (USA), his master's degree in optical engineering from the University of Arizona (USA) and his Executive MBA from INSEAD (France). He is also chair of the executive committee of SPIE and a member of A3, the Association for Advancing Automation.

Marisa Edmund succeeds Robert Edmund, who is retiring, as the new chair of the EO board. She will also continue to serve as chief sales and marketing officer.

"I am delighted and honored to transition chair responsibilities to Marisa," noted Robert Edmund. "With her extensive experience, strong leadership qualities, and inspiring vision, Marisa is uniquely positioned to guide Edmund Optics into the future. I am also very proud to see our Edmund family legacy continue."

Marisa has over 25 years of experience in the photonics industry with Edmund Optics as a global leader in direct marketing, sales, organizational development, and strategic planning. Marisa obtained her BSBA from Georgetown University School of Business, receiving top honors, and then pursued her Master's in Business Studies at Stockton University. She has served as vice chair to the board of directors since October 2020.

In the newly created position of senior vice president of corporate development at EO, James Fisher will lead business development strategies, mergers and acquisitions, and other strategic investments and activities.

Fisher has 20 years of photonics industry experience, served on EO's board of directors since 2018, and was general manager of MKS/Newport's photonics business unit. He holds an MBA from USCand a Bachelor of Science in engineering from the University of Illinois-Urbana.

www.edmundoptics.com

New managing director of Fraunhofer ISIT

Source: Fh. ISIT / E. Shambroom Phot.

Prof Dr Holger Kapels

The executive board of the Fraunhofer-Gesellschaft has appointed Prof Dr Holger Kapels as managing director of the Fraunhofer Institute for Silicon Technology ISIT in Itzehoe. In this position, he succeeds Prof Dr Axel Müller-Groeling, who moved to the executive board of the Fraunhofer-Gesellschaft in Munich.

Prof Kapels will initially take over the management of the institute as acting managing director until a new institute director is finally appointed by a joint committee of the Fraunhofer-Gesellschaft and Kiel University (CAU) within the framework of a public call for applications.

Holger Kapels has been working at Fraunhofer ISIT since 2014. In recent years, he was head of the power electronics business unit and deputy institute director. He brings a wide range of experience from industry to his new role. He has worked in research and development for several years, most recently as head of development in an industrial company.

In addition to his activities at Fraunhofer ISIT, Holger Kapels is also professor of semiconductor devices of power electronics at CAU Kiel and seeks to expand the cooperation between the institute and the university.

www.isit.fraunhofer.de

Quix Quantum appoints new CEO

Dr Hans van den Vlekkert (left), Dr Ing Stefan Hengesbach (Source: QuiX Quantum)

To build the world's most powerful quantum photonics processors and scalable, plug-and-play quantum computing solutions, Quix Quantum introduces Dr Ing Stefan Hengesbach as newly appointed CEO.

Having been in the photonics industry for more than ten years, Hengesbach possesses an extensive background in photonics and quantum optics. Prevalent through his education and numerous publications, he has dedicated his career into mastering the industry. Founder Dr Hans van den Vlekkert is retiring from the operational side of the business and will remain with the company as a director and shareholder.

Dr Hengesbach has had his dissertation awarded the Borchers Badge of RWTH Aachen University, as well as his research in the field of laser technology with the renowned Hugo Geiger Prize of the Fraunhofer Gesellschaft and the WLT Prize of the Wissenschaftliche Gesellschaft Lasertechnik eV.

He took over as CEO in May, after previously having served as managing director of the quantum startup Qant in Stuttgart, Germany.

www.quixquantum.com

Automation Technology with new marketing management

The northern German camera manufacturer Automation Technology (AT) has promoted Nina Claaßen to

Source: Automation Technology

Daniel Seiler congratulates Nina Claaßen

head of marketing. This is a step on the way to expanding the company's internal and external communication channels.

Claaßen has been working in marketing at AT for two and a half years. In this role, she initially redefined the company's corporate identity and revised its branding. She also worked to improve communication channels and create more transparency. As head of marketing, she now focuses on strengthening AT's visibility.

Having worked as a journalist herself for more than 15 years in the capacity of senior editor at Funke-Mediengruppe and as press spokesperson at ADAC, Claassen has a wide-ranging network of contacts from every industry. "Our 3D and infrared cameras are used in every sector worldwide. As a result, we always have exciting stories to tell," says the native of Lower Saxony.

The next goals of the AT marketing team are now to increase video and webinar production and to strengthen the company's visibility, e.g. at trade shows.

www.automationtechnology.de

Tribute to Leonardo Del Vecchio

The board of directors of Essilor-Luxottica paid homage to chairman Leonardo

Source: EssilorLuxottica

Leonardo Del Vecchio, 1935 – 2022

Del Vecchio who passed away peacefully in June. They said he will forever be remembered for his values, robust leadership, passion, exceptional character as well as his dedication toward the company and its employees.

The board appointed Francesco Milleri as its new chairman for the remaining duration of his mandate. Milleri will also carry on assuming his term of office as chief executive officer of Essilor-Luxottica.

The board further decided to examine the benefits of appointing a lead director among its independent members. A final decision will be taken in this regard before year-end. The board confirmed Paul du Saillant as deputy chief executive officer of Essilor-Luxottica.

At the meeting, the board also co-opted Mario Notari as a new director. Mario Notari is a full professor of company and business law at Università Bocconi in Milan and member, PhD board in business law at Università Bocconi. He is also founder and partner of ZNR notai, public notaries and lawyers in Milan. He was director of Luxottica Group SpA. from 2015 to 2018 and is a director of Delfin S.à r.l. Mr Notari will be considered as a non-independent director on the board.

www.essilorluxottica.com

Ximea presents new member of the management board

Michael Cmok has been with the company from the beginning. His expertise and organizational skills have contributed to the current success of the company.

Source: Ximea

Michael Cmok

"I am excited and honored to join the circle of my fellow managing directors at Ximea. The fresh momentum from our recent generational changes will help us realize our ambitious objectives and build upon the success that Ximea has achieved since its inception. I am intrigued to explore everything that is yet to come!" says Michael Cmok.

www.ximea.com

Alio appoints new sales and marketing director

Peter Lehner is to increase the market share in the industry for Alio Industries as new sales and marketing director.

Source: Alio

Peter Lehner

Alio was recently acquired by Allied Motion and will now be able to make its motion control solutions more accessible. To expand its customer base, the company has appointed Peter Lehner as sales and marketing director.

Lehner has spent the last ten years in sales at Keyence and Attocube, where he led and grew the motion and sensing sales team.

He holds a bachelor's degree in Business Administration and Economics from the University of Passau and a master's degree in business law (LL.M) from the Technical University of Nuremberg.

https://alioindustries.com

Buehler names new operations director

Marek Domanski is the new operations director at Buehler ITW Test & Measurement since the beginning of the year. From the company's headquarters in Lake Bluff, Illinois, USA, he coordinates and manages the production and sourcing of suppliers of all the company's systems for materialography and hardness testing.

Domanski comes from Loma, the manufacturer of inspection equipment for the food, packaging and pharmaceutical industries, which is also part of the group, where he managed production, purchasing and quality assurance for three years. Prior to that, he gained 14 years of experience in production at other industrial companies. He

Source: Buehler

Marek Domanski

cites short delivery times and reliable delivery dates as his primary goals.

www.buehler-met.de

MKS Instruments strengthens management team of its photonics solutions division

Since July 2022, Thorsten Frauenpreiss directs global sales and service of the Newport, Spectra-Physics and Ophir brands as the new vice president global sales and service of MKS' photonics solutions division. To fill his previous role, MKS has recruited the experienced manager and laser expert Markus Ruetering. In addition to his responsibilities as vice president sales and service for Europe, the Middle East, India and Africa (EMEIA), Ruetering will also assume management at the MKS site in Darmstadt in the near future.

Ruetering knows the laser industry from various perspectives. The graduate engineer started his career in research and development at Rofin-Sinar before steadily developing in the direction of sales management. Ruetering held various management positions during his 22-year tenure with the laser manufacturer. He then moved to Laserline, where he was responsible for the company's worldwide sales and marketing as sales director.

"After thirty years of working in the field of high-power lasers, I am particularly attracted by the broad MKS portfolio, which goes far beyond laser technology itself," explains Ruetering. He adds, "My goal is to consistently expand the 'surround the workpiece' concept throughout EMEIA, which offers comprehensive photonics solutions from a single source."

Thorsten Frauenpreiss

Markus Ruetering

All images: MKS

Thorsten Frauenpreiss, who himself was appointed to a global role after only fifteen months at MKS, believes that the conditions for this are ideal: "I have known Markus Ruetering for many years and value his expertise. He is ideally suited to drive MKS' outstanding development in the photonics sector."

www.mksinst.com

Umicore Coatings Services appoints new managing director

The manufacturer and supplier of infrared precision optical filters and coatings has promoted Mark Naples to managing director. The previous commercial manager, has almost two decades of experience working across the optics, sensing, and imaging industries.

His appointment comes at a key time for the business, as the broader Umicore group reaffirmed its position as a leader in clean mobility materials and complex recycling for 2030 and beyond.

Reflecting on his appointment, Naples said, "I am delighted to have the opportunity to lead the coating services business. We have a fantastic and dedicated team in Dundee, who all work hard to keep us at the forefront of a competitive industry. The staff is the best at what they do, so it will be my job to bring unique insight into the wider business."

Source: Umicore

Mark Naples

https://eom.umicore.com

Palomar Technologies names new managing director for its European operations

The global leader in delivering total process solutions for advanced photonics and microelectronic device packaging headquartered in Carlsbad, California, announced the appointment of Thorsten Scheidler as the new managing director for its European operations, Palomar Technologies GmbH in Erlangen, Germany, effective October 1, 2022. Mr Scheidler replaces Josef Schmidl who is retiring after more than thirty years with Palomar Technologies.

Thorsten Scheidler, sales director Europe for SST Vacuum Reflow Systems, has more than fifteen years of sales and technical support experience within the power electronics and semiconductor industries in Europe. He has been instrumental in implementing sales strategies for Palomar's wholly owned subsidiary, SST Vacuum Reflow Systems in the EMEA market.

Source: Palomar Technologies

Thorsten Scheidler

www.palomartechnologies.com

New deputy director for IFSW

Since August 2022 Andreas Michalowski is professor at the IFSW at the University of Stuttgart, focusing on laser technology in manufacturing. This professorship was newly established within the framework of the Innovation Campus Future Mobility. Together with Thomas Graf, he now heads the Institut für Strahlwerkzeuge (IFSW).

Michalowski studied physics at the Technical University of Dortmund, graduating with a diploma degree. He then worked as a research assistant at the IFSW, focusing on materials processing with ultrashort laser pulses, which was also the thematic focus of his doctorate.

In 2011 he started at Bosch Research as a scientist and was responsible for process fundamentals and simulation for machining with ultrashort pulses. From 2018 on, he was a senior expert responsible for virtual process development and later also for hybrid modeling (physics and machine learning) for laser material processing.

www.ifsw.uni-stuttgart.de

Source: Heidi-Maria Götz, IFSW, U Stuttgart

Director Prof Thomas Graf (left) and deputy director Prof Andreas Michalowski

Open multiplexing offers researchers more choices

Leica Microsystems has introduced a new generation of its multiplexed imaging solution

The more scalable and efficient multiplexing platform addresses spatial cell biology and function within the tissue microenvironment. This offers researchers the freedom to select from over 350 rigorously validated antibodies to design their studies in their own way and a proven workflow to image sixty-plus biomarkers in a single tissue section.

Cell DIVE multiplexed imaging solution workstation

The new Cell DIVE ClickWell coverslip-free slide holder enables users to automate their workflows based on their unique needs. The improved workflow reduces the risk of unnecessary tissue damage and improves sample processing time while still offering the researcher the freedom to choose the staining method that is best for their research.

"Cell DIVE enables scientists, particularly those working in cancer research, to map normal and diseased tissue by cell type, biomarker profile, and specific features better than ever before," says James O'Brien, vice president of life sciences at Leica Microsystems. "The solution enables open multiplexing by making the manual workflow more efficient. It also gives researchers the power to choose their automation strategy to scale their research as it suits them."

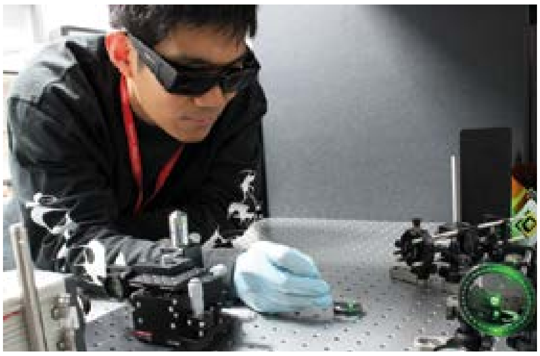
Cell DIVE sample staining occurs off the imager, allowing the user to process many slides through staining and dye inactivation steps in batches, thereby enabling scalability even without automation. ClickWell provides flexibility to automate sample staining, enabling the use of automated pipetting systems and autostainers. Researchers can also add a robotic arm to support unattended imaging of many samples.

www.leica-microsystems.com

New photoacoustic endoscope fits inside a needle

Tiny probe lays groundwork for high-resolution 3D imaging during clinical procedures

Researchers in London have created a photoacoustic imaging endoscope probe that can fit inside a medical needle with an inner diameter of just 0.6 millimeters. Photoacoustic imaging, which combines light and sound to create 3D images, can provide important clinical information, but until now the instruments have been either too bulky or too slow for practical use as forward-viewing endoscopes.



A photoacoustic imaging endoscope probe can fit inside a medical needle with an inner diameter of just 0.6 millimeters. (Source: T. Zhao, KCL)

"Traditional light-based endoscopes can only resolve tissue anatomical information on the surface and tend to have large footprints," said Wenfeng Xia from the King's College London School of Biomedical Engineering & Imaging Sciences. "Our new thin endoscope can resolve subcellular-scale tissue structural and molecular information in 3D in real time and is small enough to be integrated with interventional medical devices that would allow clinicians to characterize tissue during a procedure." The ultrathin endoscope was developed through a close collaboration between King's College London and University College London. It consists of two optical fibers, each roughly the diameter of a human hair.

"The imaging speed of this photoacoustic endomicroscopy probe is two orders of magnitude higher than those previously reported," said Xia. "It could eventually allow 3D characterization of tissue during various minimally invasive procedures such as tumor biopsies. This could help clinicians pinpoint the right area to sample, which would increase the diagnosis accuracy."

Photoacoustic imaging works by shining pulses of light onto absorbing structures in the body such as red blood cells or DNA. The structures then generate acoustic waves that can be detected by ultrasound sensors and used to form images that can resolve molecular, structural and functional information from below the tissue surface. Although fiber-based photoacoustic endoscopy probes have been developed, they usually require a bulky ultrasound detector or have a low imaging speed. In the new work, the researchers overcame both of these challenges by combining wavefront-based beam shaping with light-based ultrasound detection and a fast algorithm to control the device. This unique combination allowed them to create an extremely small probe without sacrificing imaging speed.

The new probe uses two thin optical fibers – one to deliver the pulsed light that generates the photoacoustic waves and the other for ultrasound detection. For the excitation light, a high-speed digital micromirror device is used to scan a tightly focused light spot. This device has nearly one million tiny mirrors that can be independently flipped at tens of thousands of frames per second to change the wavefront of the light so that it can be focused and scanned quickly. For the ultrasound detection, the researchers developed an optical microresonator that could be fabricated on the tip of an optical fiber. When sound waves hit the microresonator, its thickness changes, which in turn modifies the amount of light that is reflected back into the fiber, allowing optical detection.

Reference: *T. Zhao* et al.: Ultrathin, high-speed, all-optical photoacoustic endomicroscopy probe for guiding minimally invasive surgery, Biomed. Opt. Exp. **13**, 4414 (2022); DOI: 10.1364/BOE.463057

www.kcl.ac.uk

Intelligent microscopes detect biological events

New control software optimizes how fluorescence microscopes collect data on living samples

Biophysicists from the Swiss Federal Institute of Technology in Lausanne have found a way to automate microscope control to image biological events in detail while limiting stress on the sample, all with the help of artificial neural networks. Their technique works for bacterial cell division, and for mitochondrial division. "An intelligent microscope is kind of like a self-driving car. It needs to process certain types of information, subtle patterns that it then responds to by changing its behavior," explains principal investigator Suliana Manley of the Laboratory of Experimental Biophysics. "By using a neural network, we can detect much more subtle events and use them to drive changes in acquisition speed."

Manley and her colleagues first solved how to detect mitochondrial division, more difficult than for bacteria such as C. crescentus. Mitochondrial division is unpredictable, since it occurs infrequently, and can happen almost anywhere within the mitochondrial network at any moment. But the scientists solved the problem by training the neural network to look out for mitochondrial constrictions, a change in shape of mitochondria that leads to division, combined with observations of a protein known to be enriched at sites of division.

When both constrictions and protein levels are high, the microscope switches into high-speed imaging to capture many images of division events in detail. When constriction and protein levels are low, the microscope then switches to low-speed imaging to avoid exposing the sample to excessive light. With this intelligent fluorescent microscope, the scientists showed that they could observe the sample for longer compared to standard fast imaging. While the sample was more stressed compared to standard slow imaging, they were able to obtain more meaningful data.

"The potential of intelligent microscopy includes measuring what standard acquisitions would miss," Manley explains. "We capture more events, measure smaller constrictions, and can follow each division in greater detail." The scientists are making the control framework available as an open source plug-in for the Micro-Manager open microscope software with the aim of allowing other scientists to integrate artificial intelligence into their own microscopes.

Swiss biophysicists have developed control software that optimizes how fluorescence microscopes collect data on living samples. (Source: EPFL)

Reference: *D. Mahecic* et al.: Event-driven acquisition for content-enriched microscopy, Nat. Meth., online 8 September 2022; DOI: 10.1038/s41592-022-01589-x

www.epfl.ch

Ultrathin dental camera with insect eye structure

Achieving diverse functional imaging with high dynamic range, 3D depth, and autofluorescence

Conventional dental photography technology has had a limitation in using inconvenient tools such as mirrors and cheek retractors. Dentists require basic teeth images from various angles, but patients feel discomfort because dentists must put a mirror into the mouth to capture the reflected teeth image through a handheld camera. Information such as tooth arrangement and the location of tooth decay can be obtained through this process. A compact intraoral dental camera can overcome the discomfort and scan the condition of teeth. However, due to the restricted depth of field and field-of-view, the conventional device has limitations in close-up and wide-angle imaging when capturing the entire arrangement of teeth.

Various species of compound insect eyes have superior visual characteristics, such as a wide viewing angle and large depth of field with compact visual organs made up of tiny lenses. However, previously developed 'insect cameras' have drawbacks in low-resolution or limited functions. Researchers from Korea Advanced Institute of Science and Technology and Korea Photonics Technology Institute recently developed a novel wide-angle insect eye camera, the biologically inspired intraoral camera (BIOC), for assorted functional imaging. Trials have demonstrated that this satisfies clinical needs.

The BIOC involves a new configuration of convex-concave lens and inverted microlens arrays (iMLA) and a single CMOS image sensor on a flexible printed circuit board in a carrier. The convex-concave lens substantially increases the field of view up to 143 degrees, and iMLAs reduce optical aberration by the scaling law.

The scientists hope that the novel wide-angle insect eye camera contributes not only to technical advances in biomedical engineering societies but that it also has a significant impact on such diverse vision applications as surveillance, smartphones, and drones. They anticipate a continuing growth of applications in the future. (Source: SPIE)

Various types of intraoral camera prototypes for usability testing. (Source: K. Kim et al. / SPIE)

Reference: *K. Kim* et al.: Biologically inspired intraoral camera for multifunctional dental imaging, J. Opt. Microsys. **2**, 031202 (2022); DOI: 10.1117/1.JOM.2.3.031202

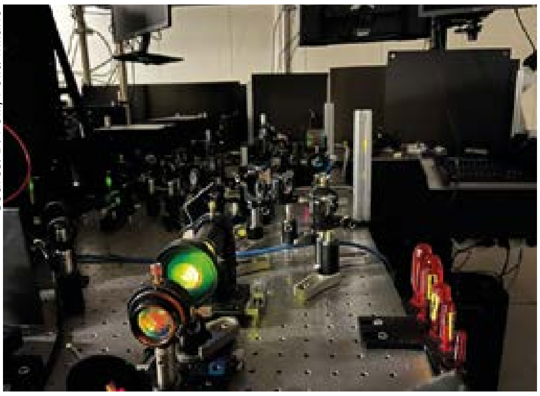
https://biophotonics.kaist.ac.kr

Speeding up Raman microscopy

Innovative microscope makes it easier and faster to diagnose cancer

Researchers have developed a label-free and non-invasive Raman spectroscopy approach that can acquire microscopic images of biological samples and identify a wide range of biomolecules with unprecedented speed and sensitivity.

Source: D. Polli, Polit. Milano



With a low pulse repetition rate, the researchers generate broadband, red-shifted Stokes pulses that cover the whole fingerprint vibrational region.

"Our work could lead to a non-invasive, label-free, and user-friendly device for clinical use," said research team leader Dario Polli from Politecnico di Milano in Italy. "This innovative microscope, coupled with deep learning-based algorithms, could eventually make it easier and faster to diagnose cancer by allowing the visualization of the chemical constituents of human tissues and cells."

The new technique is based on coherent anti-Stokes Raman scattering (CARS) microscopy. CARS microscopy produces images based on the vibrational signatures of molecules by exploiting the interaction between ultrashort laser pulses and biological samples. The new approach provides access to the hard-to-detect region of the vibrational spectrum known as the fingerprint region, which spans from 400 to 1800 cm^{-1}. Although many individual compounds can be identified using their vibrational fingerprints in this region, it tends to produce weak signals that are difficult to detect.

This new work is part of the Crimson project funded by the European Commission, which aims to develop a turnkey imaging device that uses vibrational spectroscopy for fast cell and tissue classification. The project's goal is to transform the study of the cellular origin of diseases to enable new approaches that could advance personalized therapy.

As a key step toward this goal, the researchers developed a CARS microscope based on a commercial laser that produces ultrashort pulses with durations of approximately 270 fs in the NIR wavelength range. They designed the microscopy system to use laser pulses with a repetition rate of 2 MHz, which is much lower than the 40 or 80 MHz used by most other CARS systems. This lower repetition rate reduces photothermal damage to the sample because it creates a delay of 0.5 ms between two consecutive pulses. It also produces a higher pulse energy and peak intensity at the focal point, which generates a stronger CARS signal and allows a faster acquisition speed.

Reference: *F. Vernuccio* et al.: Fingerprint multiplex CARS at high speed based on supercontinuum generation in bulk media and deep learning spectral denoising, Opt. Exp. **30**, 30135 (2022); DOI: 10.1364/oe.463032

www.fisi.polimi.it

Lithoptripsy with thulium fiber lasers

More efficient minimally invasive procedure possible

A new thulium fiber laser system may provide improved outcomes in the treatment of urinary stones for pediatric patients, compared to the current standard for laser lithotripsy. Based on their experience as early adopters of the new technology for treatment of pediatric urinary stones, Christopher Jaeger, MD, and colleagues of Boston Children's Hospital found a higher stone-free rate with the superpulsed thulium fiber (SPTF) laser, compared to standard low-power Ho:YAG lasers.

Source: Olympus

New super-pulsed thulium fiber laser improves treatment results in pediatric patients with urinary stones.

The researchers evaluated their initial experience with the SPTF laser system in pediatric patients with urinary stones located in the kidney and/or ureter undergoing treatment with laser lithotripsy. In this minimally invasive procedure, an optical fiber is placed in the urinary system through an instrument called a ureteroscope. Laser energy is then delivered through the fiber to break up the stones into pieces small enough to pass in the urine. 93 patients were treated using low-power Ho:YAG lasers and 32 using the recently introduced thulium fiber laser. The two groups were similar in terms of age, sex, and number, size, and location of stones.

On their first imaging scan after treatment, 62 % of children were free of any residual stone fragments. The stone-free rate was significantly higher for children treated with the SPTF laser.

The researchers note that they were early adopters of the SPTF laser system noting its technical advantages over Ho:YAG technology, including a shorter wavelength leading to superior stone ablation efficiency. The beam can be delivered in continuous or pulsed modes across a wide range of energy and frequency settings. The SPTF is also more energy-efficient than Ho:YAG lasers, which can require a complex refrigeration system to dissipate heat. In contrast, the thulium fiber laser unit requires only a fan, resulting in a smaller and much quieter machine. (Source: Wolters Kluwer Health)

Reference: *C. D. Jaeger* et al.: Comparing Pediatric Ureteroscopy Outcomes with SuperPulsed Thulium Fiber Laser and Low-Power Holmium:YAG Laser, J. Urol. **208**, 426 (2022); DOI: 10.1097/JU.0000000000002666

www.childrenshospital.org

SPIE election results announced at general meeting

Zygo Corporation's Peter de Groot elected into SPIE presidential chain

Peter de Groot, chief scientist at Zygo Corporation, has been elected to serve as the 2023 vice president of SPIE, the international society for optics and photonics. With his election, De Groot joins the SPIE presidential chain. He will serve as president-elect in 2024, and as the society's president in 2025. Alongside de Groot as vice president, Bernard Kress, director of XR hardware at Google, will serve as the 2023 SPIE president while the University of Arizona's Jennifer Barton will serve as president-elect.

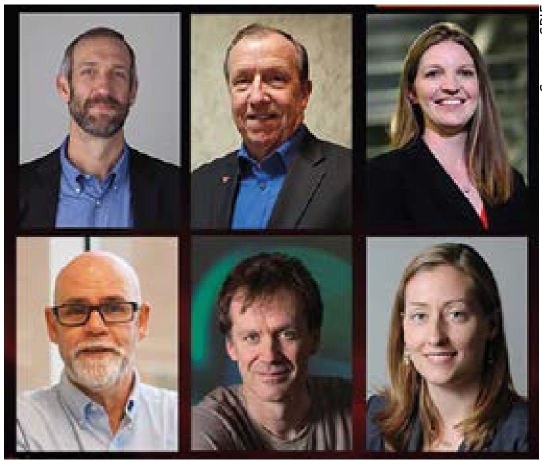
SPIE president Anita Mahadevan-Jansen, a professor at Vanderbilt University, made the announcement along with other election results at this year's annual general meeting of the society during SPIE Optics + Photonics. Terms begin on 1 January 2023.

At Zygo, de Groot works on the invention and development of new optical metrology instruments and applications. In addition to 140 patents for new optical instruments and techniques, he has published 200 technical papers, tutorials, and book chapters in physics, education, optics, and metrology.

De Groot, an SPIE fellow, has a long-time involvement with SPIE. He has served as both member and advisor to the board of directors, and is a current member of the financial advisory committee and chair for the symposia committee. De Groot has presented more than fifty papers at SPIE conferences, organizes SPIE conferences, and offers professional short courses in optical metrology. In 2016, he received the society's Rudolf Kingslake Medal for the most noteworthy original paper in the journal Optical Engineering.

"I am delighted to have been chosen to serve as the next vice president – and, eventually, president – of SPIE," said De Groot. "There has never been a more exciting time to be in optics and photonics, nor a more challenging time for SPIE to adapt to a rapidly changing professional environment. All of us at SPIE share the vision of a more inclusive, global, effective, and sustainable home for accelerating light-based research, supporting new product development, and advancing career opportunities for both rising and established scientists and engineers."

Jim McNally, CEO of StratTHNK Associates, was elected to serve as the 2023 SPIE secretary/treasurer. The following newly elected society directors will serve three-year terms from 2023 – 2025: Jessica DeGroote Nelson, Edmund Optics' senior director of optical product development, David Hagan, Pegasus Professor and dean of CREOL, the College of Optics and Photonics at the University of Central Florida, Miles Padgett, Royal Society Research Professor and Kelvin Chair at the University of Glasgow, and Laura Waller, professor at the University of California, Berkeley.



Source: SPIE

Top row (l – r): Peter de Groot, Jim McNally, Jessica DeGroote Nelson. Bottom row (l – r): David Hagan, Miles Padgett, Laura Waller

https://spie.org

Ulrich Krauss is the new chairman of Spectaris

CEO of Analytik Jena was elected with a clear majority of votes at the Spectaris general meeting

Ulrich Krauss succeeds Josef May, who led the association for fifteen years. "In all these years, Josef May was a central driver and opinion leader, a figure of identification, but also a valuable support. All of this on a completely honorary basis, in addition to his responsible position at Silhouette," emphasized Spectaris managing director Jörg Mayer at the farewell.

Krauss also paid tribute to the achievements of his predecessor and summarized his goals as the new chairman: "I would like to further sharpen the relevance and profile of the association in the political and public spheres, while helping to shape the relevant industrial policy issues. Vision, understanding, clarity and agility – that is what the association should and will offer its members under my leadership."

Krauss spent his professional life to date at Spectaris member companies, including as CEO at Carl Zeiss Meditec and as managing director sales and marketing at Carl Zeiss Vision International. He brings significant experience to the heterogeneous umbrella association structure of Spectaris, which is characterized by the coexistence of optics, photonics, analytical and medical technology.

Matis Kuchejda, managing director and owner of Schmidt und Haensch GmbH & Co, was elected treasurer for another two years. André Schulte was also re-elected as vice chairman.

Dr Bernhard Ohnesorge, managing director of Carl Zeiss Jena, was newly elected as vice chairman. Ohnesorge is also chairman of the photonics association at Spectaris.

Source: Spectaris / Sablotny

(l – r) Dr Bernhard Ohnesorge, Ulrich Krauss, Mirjam Rösch, Josef May, André Schulte

May also resigned his consumer optics chairmanship after 17 years. Mirjam Rösch, commercial director GAS and managing director at Hoya Lens Deutschland, was elected as his successor at the Consumer Optics Industry Day.

www.spectaris.de

EMVA appoints business development manager

Oliver Scheel will drive networking internally and externally in the vision tech sector

The European Machine Vision Association (EMVA) appointed Oliver Scheel as business development manager, effective September 1st. Central to this role will be the expansion of the exchange among industry participants, both inside and outside the association, as well as the dialogue with vision tech users, who will be increasingly involved in the association's work in the future. The role will also support the continued growth and visibility of the EMVA as the leading European vision trade association. Scheel has long been familiar with the machine vision industry. He worked for thirteen years as commercial manager for Wiley-VCH's trade magazines 'inspect – World of Vision' and also 'PhotonicsViews'. He then spent three years as sales director for a publishing house in Stuttgart. Most recently, he held the position of marketing director at a non-university research institution of Baden-Württemberg, which conducts research projects in the field of artificial intelligence, among other things.

Source: Wiley-VCH

"I am very much looking forward to getting back in touch with the vision community and our EMVA members as well as potential new members. As such I am thrilled to meet the industry during Vision 2022 in Stuttgart," says Scheel.

www.emva.org

EPIC and IVAM form strategic partnership

Synergy effects, especially for industry events, have been identified during a personal exchange

Micro and nanotechnologies are elementary for manufacturing, positioning, coating, finishing and quality assurance of optical components and for the further development of photonic processes. For this reason, the IVAM Microtechnology Network is continuously deepening its activities in the in the field of optics and photonics applications.

EPIC – European Photonics Industry Consortium – and IVAM have established a strategic network partnership for this purpose. At the W3+ Fair in Wetzlar in July – after a two-year break – there was finally the opportunity to seal this with a handshake.

IVAM CEO Dr Thomas Dietrich and EPIC director general Carlos Lee exchanged views on their further strategic cooperation. A memorandum of understanding (MoU) had already been agreed.

EPIC director general Carlos Lee (left) and IVAM CEO Dr Thomas Dietrich (Source: EPIC)

The cooperation will pay off in particular for jointly organized trade events. As a partner, EPIC has for several years been organizing the session on 'Photonics' at the 'High-tech for Medical Devices' specialist forum, which takes place in parallel to the IVAM joint booth at Compamed/Medica, for example.

www.epic-assoc.com
www.ivam.de

Anna Mårtensson joins EPIC as marketing manager

The European Photonics Industry Consortium (EPIC) has become the largest industry association globally, with more than 800 members, within the last few years. To address all the needs of its members, EPIC has strengthened its team by recruiting Anna Mårtensson as a marketing manager.

Anna is from Stockholm, Sweden, and has more than twenty years of marketing experience working for Hamamatsu Photonics. She studied marketing at Berghs School of Communication. Her knowledge in Nordic and European marketing, graphic design, and her background in the photonics industry brings high value to EPIC. In her new role she will be supporting EPIC in all the communication activities of the association as well as the EU-funded initiatives.

www.epic-assoc.com

"To keep your balance, keep moving"

European Photonics Industry Consortium with an epic restart of events after the summer break

Networking coffee break during the EPIC Meeting at Imec facilities

EPIC Quantum Photonics Summit

"Life is like riding a bicycle. To keep your balance, you must keep moving", wrote Albert Einstein in a letter to his son. And at EPIC we are doing our best to keep riding over Europe to connect the photonics community.

EPIC Meeting on CMOS-Compatible Integrated Photonics

On September 7 and 8, more than eighty people joined this EPIC Meeting at Imec's headquarters in Leuven, where we discussed the transition to 300-mm wafers, and how the silicon platforms can manage heterogeneous integration with new materials. One of the main issues addressed was the volume scaling of integrated photonics to be able to work with a silicon foundry. As Michael Lebby, CEO of Lightwave Logic, notes "every silicon foundry around the world has realized that photonics and PICs offer the potential for foundries to run more wafers, especially in the form of hybrid PICs. This means that foundries are now asking hard questions of the photonics industry, while the photonics companies are working hard to achieve foundry PDKs". You can imagine how vibrant the debate was during the coffee breaks, and when Philippe Absil, vice president R&D at Imec, says, "This event shows again that EPIC brings the whole of the photonics community together to discuss the future of our field," we can only say a humble thank you for your trust!

EPIC Industrial Quantum Photonics Technology Summit

Same dates but in a different location, another EPIC team was diving into the amazing world of photons and qubits at the University of Glasgow. "Photonics quantum computing is now one of the big gamers of the quantum race and promises to deliver solutions to current problems", explains Valérian Giesz, CEO and co-founder of Quandela. Indeed, during the event, some of the questions that sounded the most loudly were how to overcome the photonic packaging issues and how to develop a quantum communication network. From an end-user perspective, Faisal Kamran, principal technology analyst at Sony, says, "Quantum technologies hold a promise to allow those much needed solutions to be realized in time before a runaway climate catastrophe."

Other fruitful EPIC events were the EPIC Meeting at the European Space Agency (13 – 14 September), the TechWatch and Run at ECOC (21 September), and the Technology Meeting at Vision (5 October). If you want to keep your balance, keep moving with us and check the agenda of upcoming EPIC events!

www.epic-assoc.com

EPIC Run at ECOC, Basel, Switzerland

Upcoming EPIC events:

- 21 October 2022
  Day of Photonics
- 24 October 2022
  EPIC Online Technology Meeting on Satellite Quantum Communication
- 7 November 2022
  EPIC Online Technology Meeting on Optical Fiber Sensing for Monitoring
- 9 – 11 November 2022
  EPIC Members Delegation to Singapore
- 14 – 15 November 2022
  EPIC Technology Meeting on Electronics & Photonics – Two Sides of One Coin, Munich, Germany
- 16 November 2022
  EPIC TechWatch on Laser and Photonics Applications at Compamed High-Tech Forum by IVAM Medica, Düsseldorf, Germany
- 21 November 2022
  EPIC Online Technology Meeting on PIC Packaging and Testing
- 22 November 2022
  EPIC Virtual Company Tour at Silicon Austria
- 28 November 2022
  EPIC Online Technology Meeting on Earth Observation
- 30 November – 1 December 2022
  EPIC VIP Breakfast at W3+ Fair 2022, Dornbirn, Austria
- EPIC TechWatch at W3+Fair 2022, Dornbirn, Austria
- 7 – 8 December 2022
  EPIC Meeting on Medical Devices at Philips, Eindhoven, the Netherlands
- 12 December 2022
  EPIC Online Technology Meeting on Photonics for Food and Beverages
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"Surround yourself and listen"

EPIC CEO interview with David Ruppel, president of IDEX Optical Technologies

EPIC's photonics technology manager Panagiotis Vergyris talked with David Ruppel, president of IDEX Optical Technologies, a specialist in the design, assembly, and coating of complex optical systems for the semicon, defense, industrial, and space markets.

Source all images: IDEX Optical Technologies

What is the background to you becoming president of IDEX Optical Technologies?
I got into manufacturing by accident. Originally, I went to university to pursue a career in law but realized after a couple of years that I wanted to do something else. I ended up working with a friend who was working in a factory, and I became fascinated seeing raw materials come in one door and finished packaged product going out the other. While I was there working on the shop floor, they brought in a consultant who worked with us to figure out how we could establish better flow, better efficiencies, and increased profits. We spent months working with the consultant and were fully committed to developing new work systems that would benefit the company. But senior management rejected all his proposals saying they would never work. I was so frustrated that I immediately went back to university to do a bachelors degree in business management. What I learned from this experience and a lesson I carried with me for the rest of my career was the remarkable energy you can get from an organization when the workforce feels deeply engaged and their ideas are listened to. During my business management course, I was recruited by Cooper Industries, an American electrical products manufacturer operating worldwide, as a production supervisor. I quickly started to apply some of the lessons I had learned, pulling the team together, aligning people around the goals, and understanding what we needed to get done for the customer. After 18 months, I was in charge of three departments and supervising around a hundred people. Being fortunate in having good mentorship and advocacy, I was highlighted as someone with potential and talent and put on a fast track program, which involved doing an Executive MBA.

I stayed with Cooper for the next seventeen years, which was a great learning experience as I gained valuable experience in different commercial and financial operations and practices. But in 2012, Cooper was acquired by the Eaton Corporation and, as I could see it was going to be a painful integration, I decided to leave Cooper and work for Herman Miller, a manufacturer of contemporary interior furnishings. Although the product was completely different, Herman Miller taught me a lot about the importance of really understanding the customers' unmet needs and building customer intimacy to develop the business. After four years, I had a yearning to go back into industrial production, so I joined a company called MTI as president and CEO, where I worked for about four years before

IDEX Optical Technologies' manufacturing facility in Boulder, Colorado with specialized optical design, polishing, and coating capabilities.

Driven by the markets' requirements, IDEX Optical Technologies designs and manufactures precise components for critical applications.

moving to IDEX and leading their optical technologies business.

What are your main products and markets?
IDEX Optical Technologies comprises five manufacturing and distribution facilities, four in the US and one in the UK. We also have distribution and regional offices in the Netherlands, France, Germany, and Singapore, and employ around 275 people across all sites. The manufacturing facilities cover a range of capabilities including optical design and tolerancing for volume manufacturing, thermal and optomechanical modelling, deep-UV, UV, visible, near-IR, and IR coating designs and assembly and alignment tolerancing through advanced metrology. We have a broad range of coating technologies from low energy e-beam evaporation to dense and amorphous ion beam sputtered coatings, and our fabrication techniques include standard polishing and super polishing for both spherical and planar optics. As regards markets, we are experiencing incredibly strong demand from the semiconductor market, particularly for inspection and metrology equipment, along with significant growth in space communications, additive manufacturing and the security and defense markets.

What are your biggest challenges going forward?
The beauty of our industry is that we can expect to see sustained growth for decades to come, particularly in areas like UAVs, 5G, and space communications. But we are also seeing strain within the economy – inflation, supply chain issues, and many economists are talking about an impending recession. There are also problems in recruiting and retaining top talent, so the main challenge will be how to grow and meet customer needs while at the same time building a solid foundation and having to deal with the economic head winds.

Personally, my challenge will be to continue to build a culture that both attracts and retains employees. One of the things I love about IDEX and IDEX Optical Technologies is its low ego, servant-leadership model that values people for who they are and emphasizes listening and trust. Basically, our aim will be to continue to engage and empower people at the deepest level of the organization to attract and retain talent, which I see as key for our future success.

If you started again, what would you do differently?
On one occasion when I was at Cooper trying to drive improvements, I didn't really pull the employees along with me and engage them in the way I should have done. What I realized was that trying to push forward an idea you think is optimal without listening to or engaging the workforce is unlikely to result in success. It is far better to implement a solution that has the full support of the workforce. It may not be what you think is optimal but getting eighty percent of what you want is better than zero.

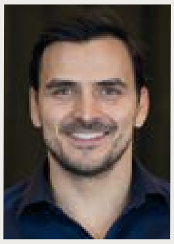
More recently, I would have started putting out purchase orders for tons of capital equipment the day I started with IDEX.

What is your advice for the next generation of entrepreneurs?
First, make sure you are pursuing something that you are really passionate about, that you are going to wake up every day and be very excited about.

Second, surround yourself with great people and listen to them.

Third, make sure you have a clear vision and set clear goals, but focus on the critical few that will help you get you there the fastest. You are better off doing one or two things really well than trying to take on ten things and not making much progress.

Author



Panagiotis Vergyris was a photonic technologies program manager at EPIC and worked on sustaining a vibrant network with more than 800 corporate members active in photonics. He actively engaged them and constantly supported them in strengthening their position in the supply chain. He has more than ten years background in photonics technology, with an extensive network in industrial and academic photonics. His primary focus is on the quantum and agri-photonics industry. Panagiotis holds a PhD in quantum photonics from the University Cote d'Azur, France, an MSc in applied mathematics and physics from the National Technical University of Athens, Greece, and an MSc in microsystems nanodevices from Greece and the Netherlands.

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“Our aim is to have a balanced just-in-time process“

An interview with Markus Spanner, CEO of Physik Instrumente, and CSO Stéphane Bussa

Physik Instrumente (PI) got through the Corona pandemic well, in spite of all the difficulties. Very well, in fact. Just how the manufacturer of positioning technology was able to grow during the crisis is explained by its chief executive officer Markus Spanner and its chief sales officer Stéphane Bussa in an interview.

Source all images: Physik Instrumente

Physik Instrumente CEO Markus Spanner (right), and CSO Stéphane Bussa

How has Physik Instrumente managed to get through the Corona pandemic?

Markus Spanner: A lot of things have started moving very quickly: digitalization for example, the continuing trend towards automation or the speed of development of medical applications. This initiated a massive increase in demand from our target markets and PI is a prime supplier in all of these sectors.

There were a combination of causes: the consistently higher demand was a surprise for everyone, and in this situation we had, and still have, to cope with supply chain problems at PI, as does everybody else. We managed to produce thirty percent more with the same production capacity as before. So we realized that we had to find solutions that would make us a reliable partner for our customers in the long term.

So you want to enlarge your production capacity. How will you achieve this?

Spanner: We had to come up with something, and we called it ‘maximum on time delivery’. This combines all the activity to do with delivering on time together with the three strategic elements: supply chain, capacity expansion and customer communication.

Our international delivery chain team has begun to bring on second source suppliers and to drive the qualification of existing suppliers worldwide so that we are no longer reliant upon just one manufacturer in a country and can also maintain the level of quality, even for increasing quantities. The pandemic taught us the lesson that we are stuck if we only have one supplier and they have problems themselves.

With regard to expanding our capacity, we will be investing a total of 63 million euros in 2021 und 2022. That is a significant amount for a group of companies that has a consolidated turnover of 250 million euros.

How have you managed to produce 30 % more with the same machines and in the same factories?

Stéphane Bussa: We started to think about the way in which we make our products at the end of 2020, the start of 2021 to become more effective and efficient. This enabled us to produce a lot more in 2021 as in the previous year, in spite of the supply chain challenges.

Spanner: It was mainly about increasing efficiency, which means increasing the throughput by changing the processes as well as the way in which we generally go about manufacturing.

Bussa: And we also employed an additional 170 people last year, mainly in Germany. We now have over 1,400 employees.

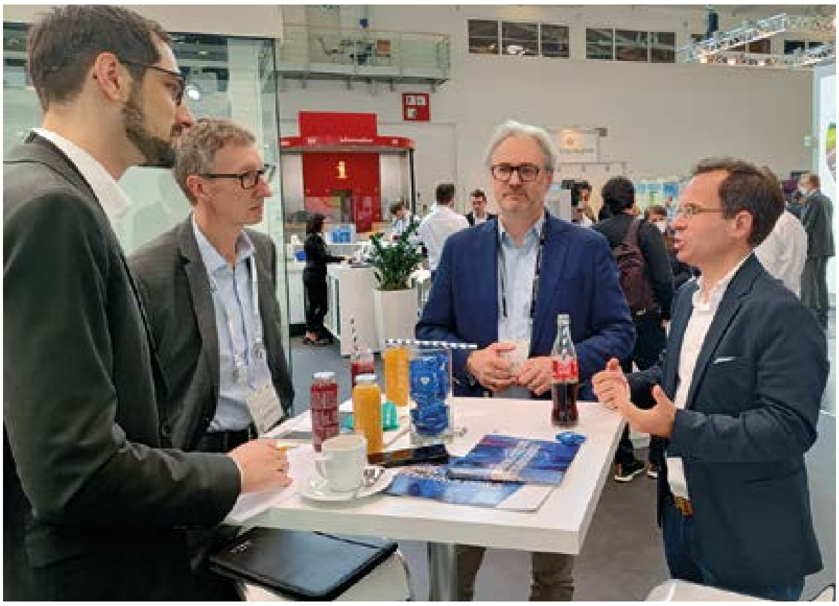
Spanner: A further 220 employees will start working with us during this year. And that is not just people in the office but also in the manufacturing areas.

Company

Physik Instrumente

Physik Instrumente (PI) with its head office in Karlsruhe, Germany, is specialized in high-precision positioning technology and piezo applications in the automation, semiconductor, photonics as well as the microscopy and biotechnology sectors. The company employs over 1,400 people, and achieved a turnover in 2021 of 243.8 million euros. PI has 498 awarded and registered patents. The company is active worldwide with nine manufacturing plants in Europe, North America and Asia as well as sixteen sales and service locations.

www.physikinstrumente.com



Right to left: Markus Spanner, Stéphane Bussa (Physik Instrumente), Oliver Dreissigacker, David Löh (Wiley)

And you say you want to increase production capacity a further 30 % this year, is that correct?
Spanner: Yes.

And this will be through digitalization and with Industry 4.0? So it revolves around software?
Spanner: Yes, but it is more than that. It is about software and automation on different levels. This enables us to increase efficiency and therefore also the throughput. That is one aspect, but it is also about the digitalization of the entire manufacturing process and decreasing the time from customer order to shipping of the product. We are also redesigning our products to make them simpler to manufacture, taking less time and effort.

Does this mean that the production at PI was not very automated before?
Spanner: That depends on the product and the quantities. We have some processes that are still largely manual, whereas others have already been highly automated for a long time. On the one hand we are increasing the level of automation generally, while on the other hand we have adjusted our production strategy. We are now following a platform strategy that allows us to manufacture very efficiently in large numbers and simultaneously to meet the individual requirements of our customers.
Bussa: That is also one of the ways in which we are becoming more of a solution provider rather than a component manufacturer. This has had a dramatic effect on all our processes because the complexity increases, which also has an effect on our supply chain.

Let me give you an example: we want to introduce an e-platform next year that will connect our ERP system with that of our suppliers. This enables our suppliers to connect directly with our production system. This is a totally new way of working together because they can see in real time what we need, and by when, whether there have been configuration changes by our customers, and so on.

We spoke before about alternative suppliers and supply chain problems. Is PI turning its back on the JustIntime principle?
Spanner: The simple answer: Just-In-Time didn't work during the pandemic. Our customers instead did the same thing during the pandemic as we did privately at home: the Germans hoarded toilet paper, the French hoarded red wine. We increased our stock at home because we were afraid that the resources would dry up. Companies reacted in the same way for the same reasons.

The situation has reversed in the meantime: just as we don't want to stockpile toilet paper anymore, companies don't want to invest in high stock levels. The target is to achieve a balanced just-in-time process – that is, a combination of low stock levels on the one hand and sufficient reserves of critical components on the other. This makes the reliability of delivery dates a decisive indicator for future customer relations – and that is our aim with this initiative: supply chain optimization, capacity growth and customer communication.

PI augmented reality app demonstrating stealth wafer dicing in action

What is involved in the aspect of customer communication in your initiative?
Spanner: We are very open and honest about these challenges. Stéphane and his team, for example, are proactively contacting the customers and explaining what measures we have taken. We want this to build our customers' trust that they can rely on us today and in the future.
Bussa: Both sides profit from this openness: as our customers need our products for their own production, they need to know if the investment will pay off. Therefore it helps them to make plans if we tell them what our situation is. And conversely we can ramp up our production capacity if we know when the customer will require which product from us. So it's a win-win all round.

*

The interview was conducted by David Löh (Inspect) and Oliver Dreissigacker (PhotonicsViews) during Laser World of Photonics 2022

One software and two lasers for three layers

ATSM: Optics module and control software for laser-based production of tribological multilayer systems

Source all images: Pulsar Photonics

▲ David Pallasch (left) discussing details of the beam alignment module (BAM) and the optic setup of a laser processing machine with a customer before final assembly in Pulsar Photonics's new location in Aachen-Verlautenheide.

Tribological coatings effectively protect heavily stressed components against wear and reduce friction. Oven processes are usually used to produce these coatings. In these processes, the substrate is subjected to an increased thermal load, whereby it must be accepted that mixing of the individual layers occurs.

As part of the German government-funded joint 'Additive laser process for the production of tribological multifunctional layers for energy-efficient systems' project, or ATSM for short, the Fraunhofer Institute for Laser Technology (ILT) and Eloxalwerk Ludwigsburg Helmut Zerrer GmbH (ELB), together with Pulsar Photonics, developed a new and innovative process for the laser-based production of tribological multilayer systems on lightweight components.

David Pallasch was the lead ATSM project manager at Pulsar Photonics and provided some insights.

After almost two and a half years of research work, the 'ATSM' research project is nearing completion. What was it about in detail and who was involved?

D. Pallasch: The aim of the research project was to develop a polymer coating system consisting of a corrosion protection layer, a tribological layer and a sacrificial layer. The three layers each consist of the PEEK [polyether ether ketone] high-performance polymer, with the different layers being enriched with various additives. The additives change the properties of the polymer according to the corresponding function of the layer. The ILT and ELB concentrated on the development of the individual layers or the composition and concentration of the additives, while we developed an optics module for the laser melting process, as well as suitable control software. Despite the difficult circumstances and travel restrictions during the second half, the consistently very good communication and atmosphere in the


Laser processing system with double scanner and double laser approach for combined heating and melting of tribological coatings developed within ATSM in the test chamber, on site at ELB.

project have led to a very satisfactory result for all involved.

Can you briefly describe the process of the laser-based method?

D. Pallasch: The PEEK powder is sprayed or painted onto the layer and then melted by means of laser radiation. In this process, several melting or preheating runs can be freely configured over the workpiece. The feeding, alignment and movement of the workpiece under the process head was done by a robot.

Looking back, what was the biggest challenge for your team in this research project?

D. Pallasch: The integration of two scan heads and two lasers for the combined heating and melting process provided exciting tasks not only for our software department, but also for our design engineers and production. Fortunately, we were able to draw on many years of experience in special machine construction during the planning and construction of the optomechanics, as well as an extensive construction kit of system technology components developed in-house.

When implementing the software, the flexibility of the process was a priority right from the start, which is why we fundamentally revised and polished our process editor that had previously only existed in rudimentary form. This now enables us not only to easily compile and configure complex processes for microstructuring, but also for other projects such as ATSM or other extensive laser processes in the future. With the new editor and process modules specially developed for ATSM, we were able to successfully implement the process with partially parallel process steps, laser control in the process and communication with the robot via i/o modules.

*

David Pallasch completed his MSc in optical technologies / electrical engineering at the TH Köln, and has been working as a software developer and project engineer at Pulsar Photonics for four years.

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Lasers in plastic processing, a big impact in the industry

A review of laser processing techniques for polymers, new developments and trendy applications in the automotive, aerospace and medical industries

Antonio Castelo-Porta


Source: Bröking Plastex / Coherent

Fig. 1 The automotive industry has regularly used lasers to cut big parts and components, such as the fenders

Plastic materials continue to be of great importance for a large number of industries. Environmental regulations are moving towards the reduction and control of their presence in the market to avoid an increase in waste, but their properties have made them the preferred material for numerous applications. The use of lasers in industrial applications has been extended to the processing of this family of materials due to their advantages when cutting, marking, drilling or welding these components.

Plastics are essential in the automotive or aerospace industries due to the need for lighter, more fuel-efficient vehicles and greater resistance to degradation. Also in the medical industry, the characteristics of plastics have made it possible to develop cheaper, safer and more resistant components that can be integrated with biological tissue. The versatility, the high speed and the efficiency of lasers have made them a very attractive tool to process these materials. Their great precision allows the manufacture of complex shapes and contours, structures with a high aspect ratio and to obtain angles not achievable with other techniques. In addition, damage and mechanical impact on the surfaces of the materials is generally reduced or minimized. However, it is important to keep in mind that the word 'plastic' encompasses a wide range of materials which, with different compositions, use polymers as a main ingredient. This diversity also affects their interaction with the energy coming from the laser, so each material has its particularities to consider before processing it.

Evolution of laser sources

Traditionally, the most frequently used sources for processing have been gas and solid-state lasers. CO_2 lasers were the first to reach the industry. They use the thermal interaction of the beam with the material to remove the amount needed to get the desired feature. They worked really well in marking applications and, in some cases, for cutting large items. The disadvantage was that there were several interesting plastics for the industry where the thermal interaction was a limiting factor on the type of processing to be performed and the quality of the


Fig. 2 Laser welded plastics parts for the automotive industry (Source: Trumpf)

final result. Variations in temperature during the laser irradiation also have an effect on the material and therefore in the properties and performance of the final product. This effect depends on the different disposition of the monomers of the polymer of interest, so it is very difficult to solve the problem without changing the composition or adding new steps in the production to protect the material, options which increase both the cost and the difficulty of the process. Nevertheless, CO_2 lasers are still used for cutting some materials that are widely used in the automotive industry and they are also very common in marking applications.

Later on, solid-state lasers provided better performance due to their higher beam quality, higher peak powers and the possibility to increase the depth of focus. The first option was crystal-based lasers such as Nd:YAG or Nd:YVO_4. These lasers have their fundamental wavelength in the region of one micrometer where several plastics feature high transmission. Again, some additives can be included to increase their absorption at 1 µm, but this extra step complicates the fabrication process. Solid-state lasers also offer the possibility to move to visible and ultraviolet (UV) wavelengths via second and third harmonic generation to take advantage of the absorption bands in these regions.

The subsequent appearance of more flexible fiber and diode lasers with improved specifications has expanded the machining capabilities, the number of materials and the types of process. One example is plastic welding, which has replaced several traditional processes in many industries. Some of its advantages are the high-quality, reproducibility, flexibility and the elimination of the residues or dust typical of other welding techniques. The most frequent process is the transmission welding method where two types of thermoplastics are joined with one another: the laser passes through the transparent mating part and the absorbing mating part is heated and melted. Both parts are pressed during the process to ensure the quality of the weld while the melted plastic solidifies completely. Laser welding is often used in parts for the automotive industry (Fig. 2).

Towards smaller features

The development of new plastic materials for markets such as healthcare or consumer electronics led to a new and growing demand for components with a smaller size and/or features. This demand was satisfied by the introduction of ultrafast lasers to the industry, which made it possible to minimize the thermal effects in these materials. With these lasers, the beam only affects the area of interest, reducing the damage and increasing the speed of the process. All these characteristics allow smaller structures with a better resolution to be manufactured. The reduction of damage when using ultrashort pulses is related to the transference of energy to the material through multiphoton excitation processes on a faster timescale [1]. It is possible to control the photo-ionization and the thermal processes to ensure that they do not affect the material and to increase the precision of the process in order to obtain high-resolution features [2]. Thanks to these properties of ultrafast lasers, a greater number of polymeric compounds can be processed today, irrespective of transparency or thickness. Moreover, the versatility of these solutions allows in some cases the same system to be used to carry out different processes, reducing the manufacturing cost and eliminating the need for post-processing.

New developments

The main laser manufacturers have been working on different solutions to improve the characteristics of their devices and to make them an attractive tool to process plastics and polymers. For example, Light Conversion offers the 'BiBurst' functionality in some of their products, an option for tunable GHz and MHz bursts with a burst-in-burst capability and very interesting applications for the polishing of bio-compatible, hydrophilic acrylic polymer surfaces. Fusion Bionic has developed direct laser interference patterning (DLIP) to perform laser surface functionalization on plastic materials and improve the performance of items requiring better biocompatibility, anti-icing or antibacterial properties. Amplitude recently developed the FemtoTrig option to solve the problems of using external modulators to control and modulate the output pulse train of the laser and to improve the quality of laser processing of curves, free forms and complex shapes in general. With this new feature, the user can freely and arbitrarily select the pulses from the oscillator pulse train that he wants to be amplified to arrive on the sample at the right time and at the right position (Fig. 3).

There is also great interest in the development of femtosecond lasers emitting at wavelengths around two micrometers. We already mentioned that many plastics have high transmission around 1 µm, which reduces the efficiency of the processing and requires the use of additives to improve the process. As these materials absorb energy particularly well in the 2 µm range, femtosecond lasers will potentially be the ideal tools for processing plastics and polymers. The radiation of a 2 µm laser penetrates through the material at an optimum distance, with the ability to be finely attenuated, provides localized heating of the material and enables the generation of controlled features. The first sources at this wavelength were extremely large and expensive, but several manufacturers have been working over the last few years on new developments based on fiber lasers to

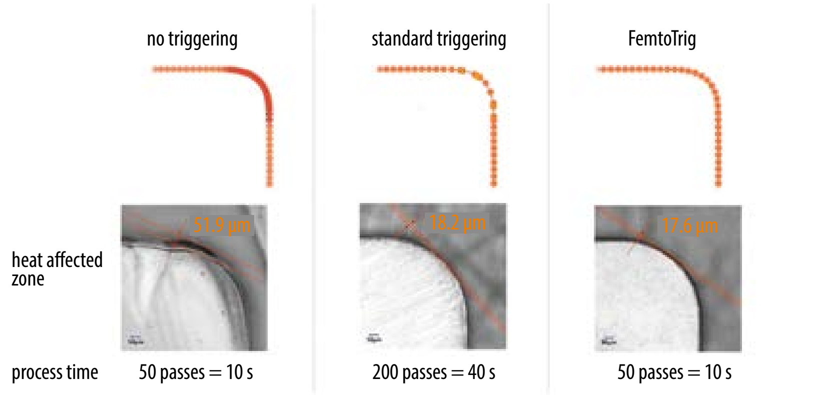

Fig. 3 Comparison of the process results of plastic materials obtained with three different modes of operation, including the FemtoTrig option (Source: Amplitude)

reduce their cost and size, improving at the same time their performance and offering different options such as pulsed and continuous wave beams. One of the best solutions is the high power, polarized, 2 µm, thulium-doped fiber laser. It combines high beam quality with the benefits of polarization, for example the ability to increase the power of the output beam using different techniques and with protection from back reflections. Stable output powers were obtained by using an all-fiber configuration with single mode fibers and fiber Bragg gratings [3]. Nowadays, most development effort is directed into obtaining sources with energies of hundreds of microjoules per pulse.

Uses in automotive and aerospace

The aerospace and automotive industries have taken advantage of the new developments in plastic and polymeric materials and they are used nowadays for sophisticated components in the most demanding applications. The main benefit for these industries is the weight reduction that increases the fuel efficiency of the vehicles, a hot topic in recent years. In addition, the resistance of plastics to oxidation and corrosion has made it possible to manufacture highly durable parts, another very critical requirement in both industries. The simplicity of manufacturing parts with the desired shape and size using several molding techniques has also made plastics and polymers among the most attractive and often used materials. An analysis by Fortune and Business Insights saw a global automotive plastics market size of 40.91 billion US dollars in 2019 and it is projected to reach $ 53.85 B by 2027, exhibiting a CAGR of 5.3 % during the forecast period. This growth is also followed by the exterior automotive plastics market whose size is projected to increase from $ 12.18 B in 2022 to $ 17.94 B by 2029 at a CAGR of 5.7 % during the 2022 – 2029 period.

Electric mobility is shaping the future of the automotive industry. Every aspect of the production of these vehicles is being analyzed to reduce the cost and at the same time improve their range and performance. Plastic materials are present, for example, in the conductive cables that distribute power throughout the car, called busbars. They are thick, ribbon-shaped metal conductors with plastic insulation around them, usually polyamide PA12. At some point in production, the insulation on the two ends of the busbar has to be removed to connect it to other components. CO_2 lasers become the ideal tool for this task due to their emission at 10 µm. This wavelength is very strongly absorbed by the plastic used for insulation and, at the same time, is highly reflected by the copper. So the laser light rapidly vaporizes the insulation, and stops when it reaches the conductor. With this process it is possible to completely remove the plastic material, avoiding the presence of any residual insulation which could interfere with the electrical connection and waste power (Fig. 4). In this application, two laser beams at a certain angle are used to remove the insulation from each side of the busbar and its edges. Apart from improving the speed of the process, with this kind of configuration there is no need to flip the part and it avoids the damage that reflected light could produce into the beam delivery system.

Carbon fiber-reinforced plastics (CFRP) are a well-established material for use in aerospace parts, but an evolution in their composition has been noticed in recent years. Thermoplastic matrices are now pushing into primary structural applications such as the fuselage, cowlings and wings because of their superior performance and advantageous production properties. Lasers are often used to cut and drill the parts, but as there is a risk of damage to those structures during this operation, several strategies have been adopted to improve the processes and to avoid durability issues related to the heat-affected zones of the material [4]. There is also great interest in repairing these parts, and several studies have been performed that use laser ablation as an alternative technique.

Plastic in medical devices

The medical industry has also benefited from the appearance of ultrafast lasers and the increase in material knowledge to develop increasingly complex solutions. Manufacturing products with bet-

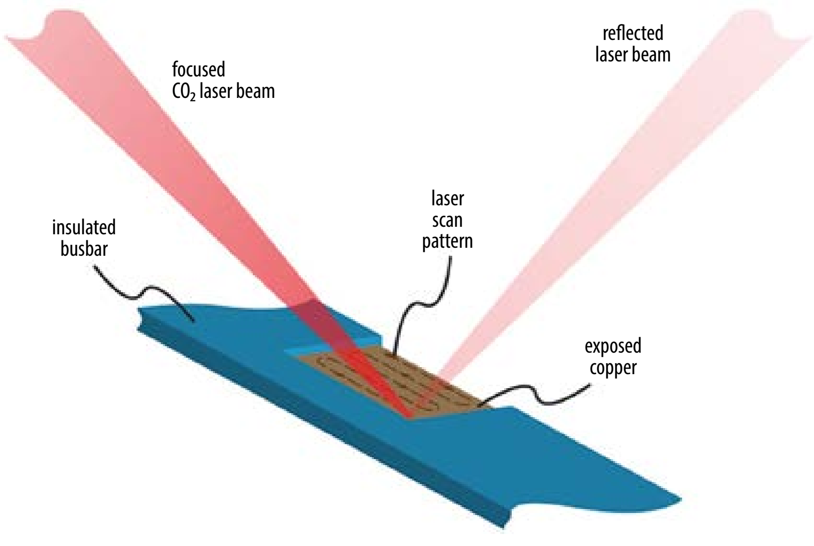

Fig. 4 Scheme of laser beam used to remove the insulation of busbars for e-mobility (Source: Coherent)

ter resolution and with tinier, higher-precision features enhances the product functionality, which can ultimately enhance or save patients' lives.

The most common process has been the marking of polymer materials. Lasers can produce an indelible high-contrast mark in the material, and they are more resistant to solvents or abrasion than other printing techniques. Laser marking offers the flexibility to directly mark a range of alphanumeric characters, logos, images or barcodes on polymers without contact with the sample. All those features can be part of the recent unique device identification (UDI), a global standard required for identification in medical products. A UDI marking consists of two parts – a machine-readable code and a human-readable code. The machine-readable part is represented either as a linear barcode or as a 2D data matrix code, and the human-readable part with numbers and letters.

Laser cutting of plastics for medical applications has shown many advantages: higher quality cutting, no residues or debris and no damage to other areas of the item. A very interesting aspect is polyimide (PI). It is a widely used material in the industry due to its mechanical strength, electrical insulation and thermal stability. In recent years, it has also emerged as one of the most interesting materials for the fabrication of medical components due to its chemical inertness and biocompatibility [5]. Its use has increased dramatically in applications such as the manufacturing of cardiovascular catheters, retrieval devices, push rings, marker bands, angioplasty, stent delivery devices, neurological devices, and drug delivery systems. Femtosecond green and UV lasers are the most suitable tools for cutting PI parts (**Fig. 5**).

Other interesting applications for the medical industry include laser ablation to selectively remove layers of substrate or coatings with micron-level precision, the drilling of small and complex features or wire-stripping to remove sections of insulation or shielding without making physical contact with the conductor. In the particular case of the new 2 µm fiber lasers, they can be used to join two components of implants and microfluidic devices by laser welding, taking advantage of the behavior of the different polymers at this wavelength range. They are also a versatile tool for manufacturing miniaturized, biocompatible and low-cost stents or catheters.

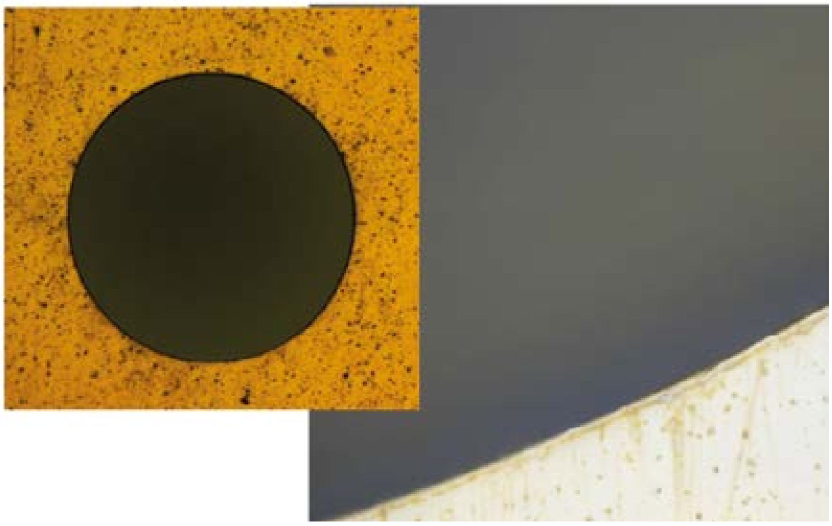

Fig. 5 PI foil (25 µm thick) cut with a femtosecond UV laser (Source: NKT Photonics)

One important point to be considered is the strict regulations within the medical sector, which normally slow down the introduction of new plastic materials. In order to help potential manufacturers, the European Commission decided to establish the MedPhab pilot line under Horizon 2020 [6]. The purpose of MedPhab is to accelerate the commercialization of diagnostic devices and instruments for treatment using photonics, and to reduce the R&D cost. The members of the MedPhab pilot line have great expertise in photonics, including the laser processing of plastic materials, so they can be a good option for the testing and validation of any new device and moving forward to ISO 13485-standardized manufacturing.

Conclusion

Laser processing of plastics and polymers has shown multiple advantages for various industries. It has made the use of new materials possible and enabled increasingly complex and compact structures, as required by industry. The number of components and devices using plastics is growing every year and new developments in laser sources are going to be essential for increasingly cheap, efficient and versatile manufacturing. Non-traditional wavelengths, shorter pulses and special options to control the beam delivery seem to be the trends for the coming years.

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Author

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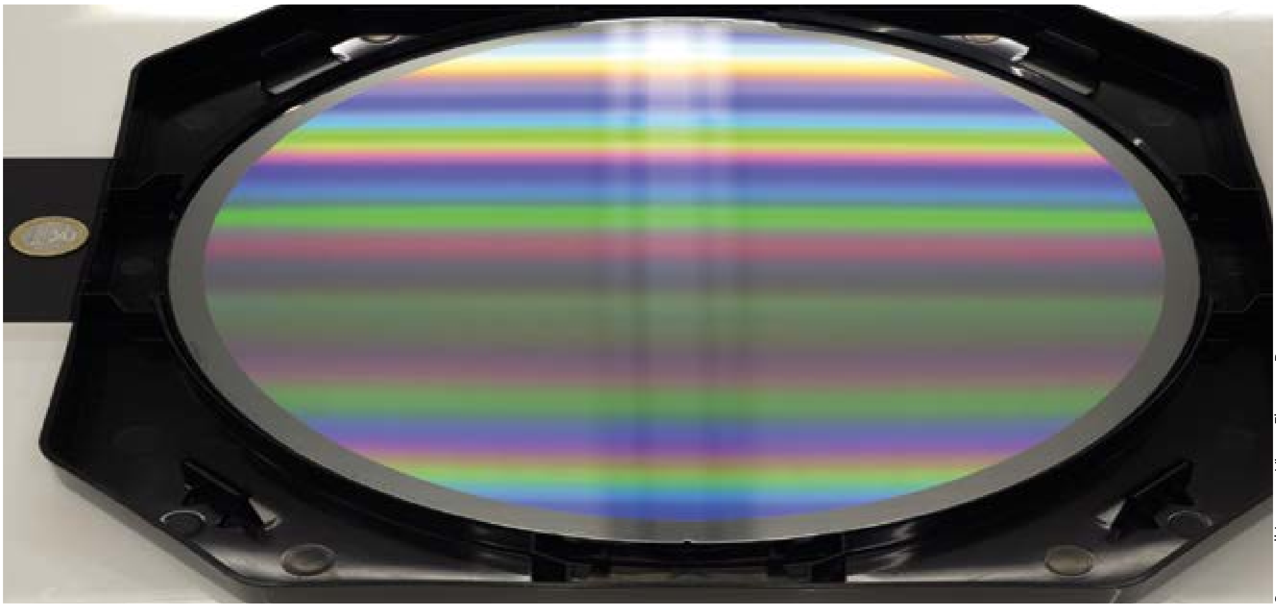
Optical metasurfaces made by cell projection lithography

Electron beam nanopatterning with high optical quality on large areas

Mathias Hädrich, Thomas Siefke, Michael Banasch, and Uwe D. Zeitner



Source all images: Vistec Electron Beam

▲ **Fig. 1** 300 mm silicon wafer with resist, completely patterned with an optical blazed grating. Patterning was performed by cell projection lithography.

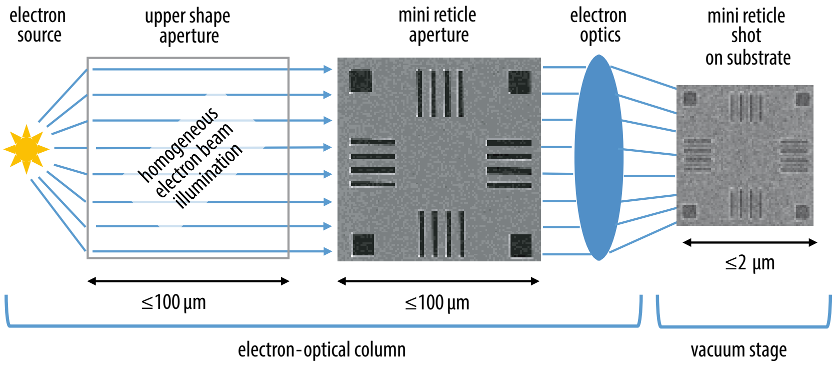
Metasurfaces offer promising possibilities for emerging photonic applications like see-through, near-eye displays. Vistec Electron Beam lithography systems with variable shaped beam (VSB) and cell projection (CP) technology provide a flexible solution to generate repetitive structures on large substrates. Excellent pattern fidelity is achieved in a feasible write-time, enabling prototyping or the manufacturing of replication masters.

Patterning the surface of a material with sub-wavelength nanostructures can create so-called metasurfaces with tailored optical properties. Metasurfaces facilitate diffractive optical elements with a flat design so that multiple optical elements can be fitted within a small form factor. This is crucial for imaging devices that are optically challenging and that need to be particularly small at the same time. Depending on the material and surface structure, metasurfaces can be used as diverse optical elements, e.g. as diffraction gratings, polarization optics such as wire grid polarizers or retarders, or for beam steering and focusing applications. When manufacturing optical metasurfaces it is critical to obtain a reproducibility and positional accuracy of the nanostructures in the deep sub-nanometer range [1] to avoid scattering artifacts caused by inaccuracies in the pattern.

Lithography methods are usually the means of choice, each of them with its advantages and disadvantages. Laser lithography, for example, is fast and flexible, but limited in resolution. Stepper lithography is fast, but comparatively expensive and limited in flexibility as it relies on optical masks. Nano-imprint lithography as a mechanical method is cheap and fast, but the pattern quality is limited. Furthermore, other lithography processes are needed beforehand to manufacture the imprint master. This is a typical application scenario for electron beam (e-beam) lithography.

Similar to optical lithography, the electron beam exposes a pattern into a resist, making the exposed area selective for further chemical processing. The resolution is in the nanometer range due to the high-energy electrons, and e-beam lithography is well-established in semiconductor fabrication, not least to manufacture masks for optical lithography. But importantly, e-beam lithography is a versatile process because arbitrary pattern data can be written directly into the resist.

The first attempts have been reported at generating optical metasurfaces on small areas by e-beam lithography with a spot beam, which works similar to an electron microscope, with an e-beam probe of only a few nanometers in diameter. However, due to the fine probe,



exposure mode	VSB	CP
number of shots	6×10^{11}	1×10^{10}
write time (estimated)	74 d 20 h	1 d 12 h
write time (measured)	–	1 d 12 h

▲ **Table 1** Shot count and write time for the effective-medium blazed grating in Fig. 3, a comparison of VSB and CP mode.

◀ **Fig. 2** Principle of cell projection, a complex mini reticle image is written in a single shot.

nanopatterning on areas larger than a few square millimeters takes an impracticably long write time with this method.

Vistec's electron beam lithography systems with variable shaped beam (VSB) and cell projection (CP) technology represent a technical solution to overcome this write-time restriction. Dense repetitive patterns can be generated on large areas efficiently and with the high pattern fidelity, positional accuracy and reproducibility that is required for optical applications.

Two platforms are offered, with the capability to fully expose an area of 200 mm or 300 mm diameter respectively. The systems are fully automated and can be equipped to process wafers and masks of different sizes and materials.

Working principle of VSB and CP

All Vistec systems utilize a 50 kV electron beam with VSB electron optics. In contrast to spot beam systems, the electron beam is defocused and illuminates a set of upper and lower rectangular shape apertures homogeneously. The projection of the upper aperture onto the lower aperture can be shifted by a fast deflection system so that the beam size is variable in 1 nm steps, down from a few square nanometers up to a maximum 2 µm × 2 µm square area. The generated shapes can be rectangles parallel to the stage axes, 45° rotated rectangles, or isosceles right triangles. The integrated data preparation software divides any given pattern data into these shapes using optimization algorithms for pattern fidelity and write time. The pattern is written in a substrate exposure shot by shot, with high-speed switching between different beam sizes. The ability to write small structures with small shots and large structures with large shots ensures a much higher productivity compared to spot beam systems for almost every kind of large-area pattern. Furthermore, the strategies of vector scan and writing with a continuously moving stage ensure efficient exposures.

CP electron optics are similar to VSB, with a set of upper and lower shaping apertures. However, the lower shaping aperture carries additional mini reticle apertures that can shape the electron beam into more complex features. The principle is shown in Fig. 2.

The apertures are homogeneously illuminated by the electron beam and the image is demagnified and projected onto the substrate by electron-optical lenses. Being able to write complex structures with highly resolved features in a single shot of up to 2 µm × 2 µm, exposures of a repetitive pattern can be accelerated by magnitudes. This is illustrated by the example in Fig. 2. The mini reticle structure that is exposed here with a single CP shot would require twenty rectangular VSB shots or several thousand shots with spot beam lithography. The reduced shot count translates into a dramatic reduction of write-time as well as improved reproducibility [2]. Moreover, curvilinear or angular structures can be written with higher precision than by arranging circular spot beam shots or Manhattan arrangements of VSB shots.

CP is comprehensively implemented in Vistec's e-beam systems in both hardware and software. On the hardware side, thousands of customized mini reticle apertures are permanently available in the system. This enables a huge variety of geometrical shapes to be produced, and design redundancy can be used to increase the service life of the apertures in case of any contamination during long-term processes. Vistec supports the customer with their mini reticle design to ensure optimal exposure results. Alongside the mini reticles, standard VSB apertures are always integrated to provide full flexibility in pattern exposure. All apertures are embedded in a multistencil chip, which can be moved by a computer-controlled mini stage. This enables changes of apertures and adjustments to take place very quickly and fully automatically.

Company

Vistec Electron Beam

As a long-standing equipment supplier, Vistec Electron Beam provides leading technology solutions for advanced electron beam lithography. Based on the variable shaped beam (VSB) principle, these systems are mainly used for semiconductor applications and advanced research such as silicon direct write, compound semiconductors, mask making, integrated optics and several new emerging markets. The company is based in Jena, Germany and maintains service and support centers in Europe, Asia Pacific, and the US.

www.vistec-semi.com

Institute

Fraunhofer IOF

The Fraunhofer Institute of Applied Optics and Precision Engineering IOF conducts application-oriented photonics research and develops innovative optical systems for the control of light. The institute covers the entire photonic process chain in its competencies. Fraunhofer IOF operates a Vistec SB350 OS electron beam lithography system with 300 mm full exposure capability and cell projection. A new Vistec SB3050-2 OS system with enhanced functionality and improved performance has also been ordered.

www.iof.fraunhofer.de

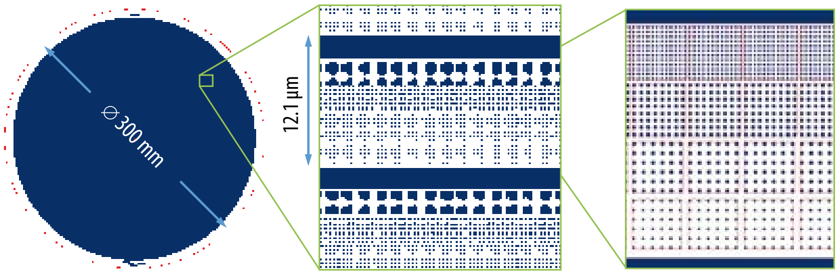


Fig. 3 Effective-medium blazed grating pattern on a 300 mm wafer. Mini reticle cells with arrays of dots were used for the CP exposure (marked by square frames in the enlarged view, smallest dot size 100 nm).

On the software side, mini reticles are completely integrated within the data preparation path, and process correction can be applied just as in VSB pattern data. Complete patterns can be built from a software library that contains the design information of the mini reticles. Alternatively, the software can organize input pattern data to be exposed with suitable CP and VSB shots. Both kinds of shot are addressed fully automatically in the exposure and are seamlessly combined.

Nanoimprint lithography master on a 300 mm wafer

The exposure of a nanoimprint lithography master was investigated in order to show the capability of CP lithography to pattern areas of relevant size. The task was to cover a 300 mm diameter silicon wafer with a metasurface that works as an effective-medium blazed grating. The optical function is generated by a dense, two-dimensional dot array with a lateral variation of the size and density of dots (Fig. 3).

Vistec's ePLACE data preparation software package was used to calculate the shot count and write times for the grating in VSB and CP exposure modes (Table 1). The total exposure area was 280 mm in diameter, with a smallest dot size of 100 nm.

In VSB mode, a write time of 74 days would be needed, which is unrealistically long, even though for every round dot only one square VSB shot was assumed. In terms of optical performance, round dots are preferable to avoid light scattering at the edges, but would need several VSB shots each for approximation, and an accordingly longer write time.

In CP mode, mini reticles with arrays of round dots (6 × 6 to 12 × 12 dots) were used to write several dots at a time with each single CP shot, as indicated in the right image in Fig. 3. As expected, this leads to a drastic reduction of the shot count, and the write time was reduced by a factor of fifty to 1 day and 12 hours. The physical exposure was accomplished within this exact time, giving evidence of the high productivity of cell projection. A photo of the wafer after exposure and chemical processing is shown in Fig. 1.

As further proof of the practical relevance, a 100 mm silicon wafer with such a grating was etched using the inductively coupled plasma (ICP) technique to transfer the pattern onto the wafer material. The demonstrator shows very reproducible pillars of 200 nm height and is well-suited as a master for nanoimprint lithography (see Fig. 4).

Wire grid polarizers of high optical quality

Wire grid polarizers (WGPs) are di-attenuating, nano-optical structures of a grating type that are used for many optical applications. TM polarized light (E-field vector orthogonal to the ridges) is mostly transmitted while TE polarized light (E-field vector parallel to the ridges) is mostly blocked (see Fig. 5a). The ratio of both transmittances, the extinction ratio, is a measure for the performance of WGPs. A special case are division-of-aperture polarimeters which require a local variation of the grating direction (Fig. 5b).

The optical performance of a WGP for short wavelengths in the UV and VUV range (here 150 nm < λ < 250 nm) is very sensitive to the line edge roughness (LER) of the template grating (see Fig. 5c) [3] with a standard deviation σ_{LER}. With modern resist technology, there is little potential for a further reduction of the statistical component in the chemical and physical patterning process. This already limits the achievable performance to an extinction ratio of 27 % compared to perfectly smooth grating lines (see Table 2). It therefore becomes crucial to eliminate additional systematic effects. A comprehensive, spatial frequency-dependent roughness model was applied in combination with finite difference time domain (FDTD) simulations to model the influence of the LER on WGPs. The pattern investigated is a WGP with a 30° rotated grating of critical dimension 73 nm and a period of 200 nm, to be exposed in VSB or CP mode respectively (Fig. 6). To establish the practical fabrication of these WGPs, write-time simulations for an area of 100 mm × 100 mm were performed.

In VSB mode, the 30° rotated lines are approximated by rectangular exposure

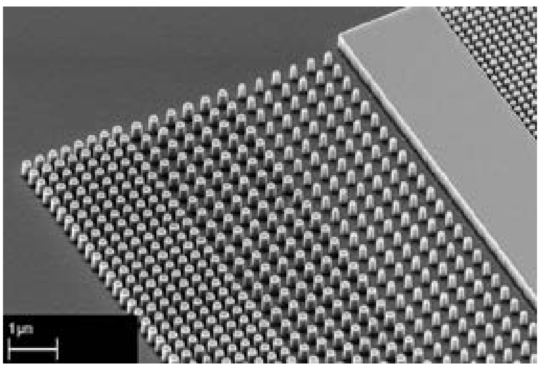


Fig. 4 SEM image of a nano-imprint master for a metasurface like described in Fig. 3, exposed with CP and etched into the wafer.

	CP	VSB / approximation accuracy	
		10 nm	15 nm
σ_{LER} in nm	3.36	3.64	6.53
s_{VSB} in nm	-	1.4	5.6
period in nm	-	78	122
number of shots	1	346	230
extinction ratio in %	27	25	9
transmittance TM in %	89	88	70
write time	6 h 15 min	67 d 18 h 40 m	45 d 13 h 20 m

Table 2 Structural and optical properties of a wire grid polarizer written in VSB or CP mode, respectively, and the corresponding write time estimation.

shots rotated by 45°. The approximation parameter describes the average offset of the shot edge from the smoothed line edge. The approximation leads to a modulation period in the lines and to a systematic VSB line edge roughness with standard deviation s_{VSB}. In the case of 10 nm approximation, the systematic LER effect is sufficiently small with an s_{VSB} of 1.4 nm. 25 % of the extinction ratio and 88 % of the transmittance (TM) can be achieved compared to a perfect grating (Table 2).

However, the shot count is a factor of 346 higher than for the CP exposure, resulting in an unrealistic write time of more than 67 days. By a coarser approximation of 15 nm, less exposure shots are necessary but the modulation effects and s_{VSB} become significant. The optical properties are also compromised, resulting in an extinction ratio of only 9 % and a TM transmittance of 70 % with respect to the ideal grating, while the write time is still much too long at 45 days.

In CP mode, the systematic LER effect is avoided, as several grating lines are written simultaneously without division into rectangles. A better optical performance is then achieved with 27 % extinction ratio, and 89 % transmittance of TM polarized light. Writing the rotated wire grid polarizer for short wavelengths takes approximately six hours with cell projection, i.e. more than one hundred times faster than the VSB exposure.

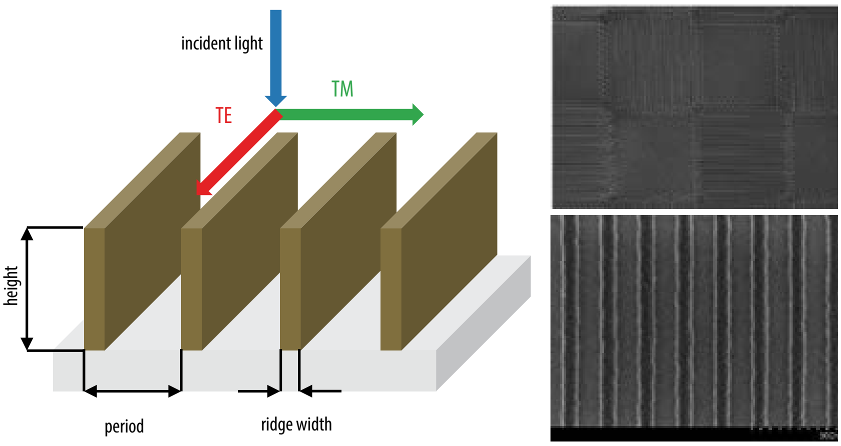


Fig. 5 (a) Schematic of a wire grid polarizer, direction of the electric field vectors is marked. (b) SEM image of the WGP array used for division of aperture polarimeter. (c) SEM image of the resist structure used to fabricate WGPs, with 73 nm lines and 200 nm period.

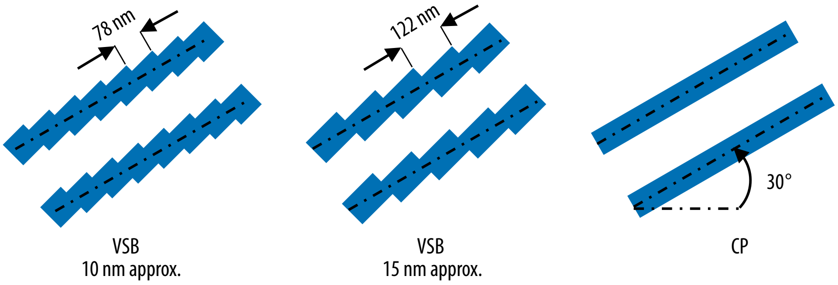


Fig. 6 Schematic illustration how angular grating lines are written VSB or CP mode, respectively. The approximation in VSB mode results in systematic effects of modulation period and line edge roughness.

Summary

The ability to write nanopatterns without a mask directly into resist at high resolution is a particular strength of electron beam lithography. The practical examples presented here demonstrate that the cell projection feature speeds up the writing of repetitive pattern by magnitudes. Simultaneously, the pattern fidelity can be significantly improved, especially in the case of curvilinear or angular structures. This opens up new opportunities for innovative optical applications.

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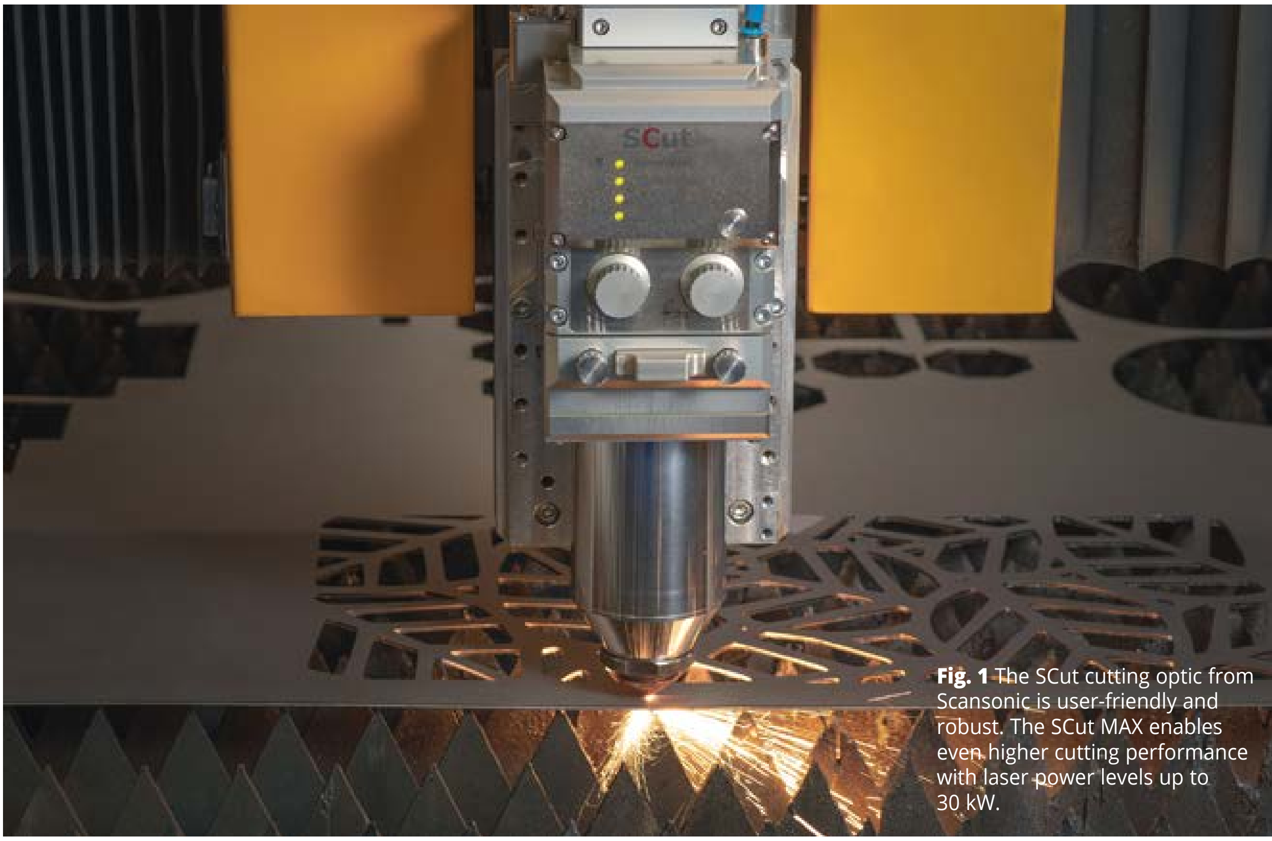
Laser optics for the perfect cut

A robust design and integrated monitoring ensure the process safety and quality of laser cutting

Marc-Gordon Griguhn



Source: Scansonic MI

Fig. 1 The SCut cutting optic from Scansonic is user-friendly and robust. The SCut MAX enables even higher cutting performance with laser power levels up to 30 kW.

For many years, the main use of lasers was in the sciences. They were used primarily in spectroscopy, measurement technology, and nuclear physics. With the invention of the diode laser, they began to be used in everyday applications ranging from CD players to communications technology. Ever-increasing performance has long since opened up further applications. For example, lasers can now even cut centimeter-thick sheet steel.

Lasers play an important role in processing metals. In addition to welding, brazing, and hardening, laser cutting is one of the established methods of laser material processing. When cutting sheet metal, for example, laser cutting is recommended as an alternative to the stamping of thin workpieces, and as an alternative to plasma cutting of thicker pieces. Laser cutting relies upon the best combination of the laser source, the guide machine, and the cutting optics. The continued refinement of laser sources and cutting optics has made it possible to cut increasingly thick sheet metals so that even steel several centimeters thick can now be easily cut. This method has a number of benefits when compared to plasma cutting, including narrower and smoother seams, superior cut-edge surface quality, and higher cutting speeds. It also offers a great deal of flexibility.

Protecting sensitive optical components

The use of lasers in metalworking presents a fundamental challenge in that the laser system's sensitive optical area – including the cutting optic that focuses the laser beam on the workpiece – must be kept completely free of contamination. Even small dust particles could have disastrous consequences. Contaminating particles absorb a portion of the laser power, causing them to become extremely hot, which can lead to the destruction of the optical components and system failure. This is why all internal components of processing optics must be assembled and operated under cleanroom conditions. Such conditions stand in stark contrast to the industrial environments where metals are cut. Dust, sparks, and smoke cannot be avoided in such environments, and may contaminate or damage the surrounding equipment. This makes dust-

Source: MicroStep Europa

Fig. 2 Flatbed laser cutting systems allow quick and precise processing of sheet metal

proof shielding critical for the sensitive optical components of a laser cutting optic.

Fiber and disk lasers as alternative laser sources

CO_2 lasers were the standard for laser cutting until just a few years ago. These have proven their effectiveness in the past, but they also have disadvantages. For example, they require the use of free-beam guidance, which brings corresponding costs for the laser cutting optic and for the shielding against the rough industrial environment. In contrast, the further development of fiber lasers has opened up new opportunities in recent years whereby improved beam quality and greater efficiency, for example, have increased power levels sufficiently to make fiber lasers well suited for cutting applications. The laser beam can be directly coupled to the optic through an appropriate optical fiber to substantially reduce the expense of dust-proof shielding.

Different machine designs for laser cutting

With the appropriate system, laser cutting optics can be used for a variety of processing geometries. In flatbed systems for processing sheet metal, a portal mechanism moves the cutting optic over the sheet in two dimensions (Fig. 2). In many cases there is also an option for bevel cutting, in which the head is tilted out of the vertical plane. The second important category is pipe cutting systems, in which the workpiece is rotated around an axis and can be moved longitudinally. This allows the processing of pipes with different cross-sections, as well as pieces with U or L-shaped cross-sections.

Regardless of the processing geometry, a laser cutting system always consists of three basic assemblies. The first is the guide machine, which includes a controller. The second is a laser source, which provides the required laser power with the appropriate beam quality. As mentioned above, fiber lasers are generally employed for this purpose. The third assembly is the laser cutting optic. Equipment and systems manufacturers generally design and produce the guide machine, but acquire the laser sources and cutting optics from specialized suppliers.

Laser cutting optic as a key component

The quality of a cut is fundamentally determined by the optimum function of the cutting optic. The purpose of the optic is to position the laser beam's focus at the correct point on the workpiece. A lens system is built into the cutting optic for this purpose and functions like a camera lens. When developing the laser cutting optics, the specialists at Scansonic concentrated their efforts on meeting user requirements for easy operation, robustness, and service (Fig. 1).

SCut laser cutting optics are suitable for both fiber and disk lasers within a frequency range of 1030 – 1130 nm and at power levels up to 30 kW. The product portfolio offers the right solution for a variety of requirements. The PRO model is recommended primarily for focal lengths of 125 – 200 mm. Its autofocus system covers a broad range, from 20 mm in the workpiece direction to 15 mm in the nozzle direction. The SCut 360 is suitable for ring mode lasers with an adjustable beam profile. Exceptionally good cut quality and greater material thicknesses can be achieved using the SCut 360 bundled with the remote laser, particularly when cutting construction steel at lower power levels. The SCut MAX, the newest member of the laser cutting optic family, is a version for high laser power levels of up to 30 kW. This ensures a robust and stable laser cutting process, even for very thick materials at high cutting speeds.

The user interface provides higher-level control to preset the cutting optic's focus position. This can be adjusted between grooving and the subsequent cut, for example to significantly improve the cut quality and to produce burr-free cuts with high-quality edges. Temperature-stable distance control is also integrated to keep the focus at the correct location during processing. It works with a low-drift capacitive sen-

Company

Scansonic MI

Scansonic MI GmbH offers systems and solutions for laser welding, laser brazing, laser cutting, and laser hardening, as well as optical sensors and process monitoring systems. The products are used especially in automotive engineering, rail vehicle construction, and electrical power engineering. Scansonic MI is a leading provider of laser-based joining systems for car body construction. The company is part of the Berlin.Industrial. Group. (B.I.G.), with headquarters in Berlin and around 300 employees.

www.scansonic.de

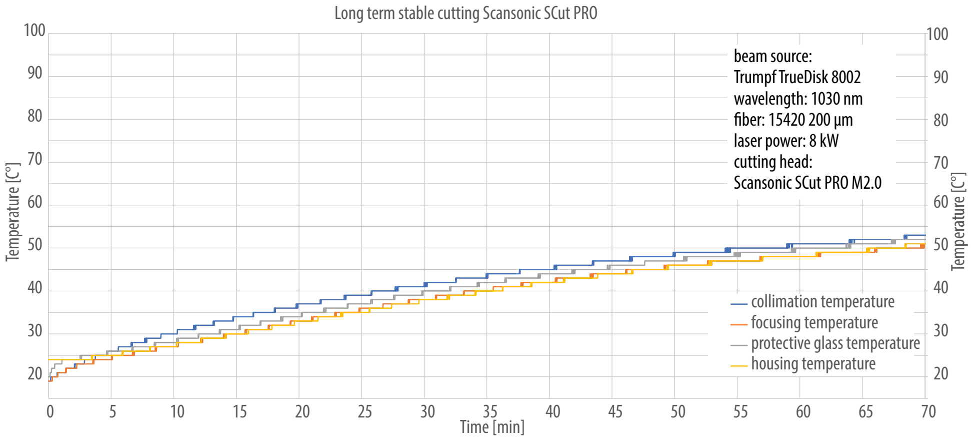


Fig. 3 The temperatures of all relevant components are continuously measured in the SCut laser cutting optic. Cutting quality remains constantly high, even in continuous operation at a power level of 8 kW.

sor to produce consistently stable cutting results, even at higher power levels and with longer processing times. The laser cutting optics have a sophisticated mechanical sealing system to prevent contamination of sensitive optical components within the cutting optic. Integrated sensors continuously monitor the integrity of the seals. If an error occurs, the operator is immediately notified and the process can be promptly stopped. This effectively prevents damage to the laser cutting optic.

Maintaining optimum alignment between the gas nozzle and the laser beam prior to the start of processing is extremely important for the quality of the cutting. Scansonic laser cutting optics have two easily accessed, front-mounted, rotary controls to adjust this alignment. These allow precise and true-to-axis horizontal adjustment. The unit's ease of operation saves a lot of time during setup, while simultaneously ensuring high-quality processing.

Status monitoring directly within the optic

In addition to their robustness, these laser cutting optics boast a comprehensive sensor system that continuously monitors the components. This allows users to respond quickly to possible changes in the cutting optic and to prevent system failure. In addition to distance control, leak detection, and process gas pressure measurement, the temperatures of all important components of the cutting optic are measured. The system also verifies that the protective glass is present, checks for contamination of optical components, and monitors humidity levels within the laser cutting optic. All sensor data from the cutting optic are analyzed and provided to the guide machine's higher-level controller (Fig. 3). This controller uses the values for complete status monitoring of the cutting optic and can immediately notify the operator when necessary. This allows the planning of essential maintenance and reduces lifecycle costs.

Optimized for minimal downtime

In addition to easy operation, easy servicing of the cutting optic is essential to allow the laser cutting of metal workpieces even in facilities that primarily manufacture small batches (Fig. 4). The developers at Scansonic took this into account as well, and made sure that equipment manufacturers can offer most repair services directly to their customers using their own trained service personnel. Scansonic can provide them with spare parts that meet stringent cleanliness requirements. This eliminates the need to return the cutting optic to the manufacturer for repairs, which in turn helps to prevent downtimes. Equipment manufacturers can also maintain a smaller inventory of replacement cutting optics for exchange during repairs.

Laser cutting technology is constantly being refined and the developers in Berlin are currently working on controller technology that includes the ability to link through a high-speed fieldbus interface.

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Source: Scansonic MI

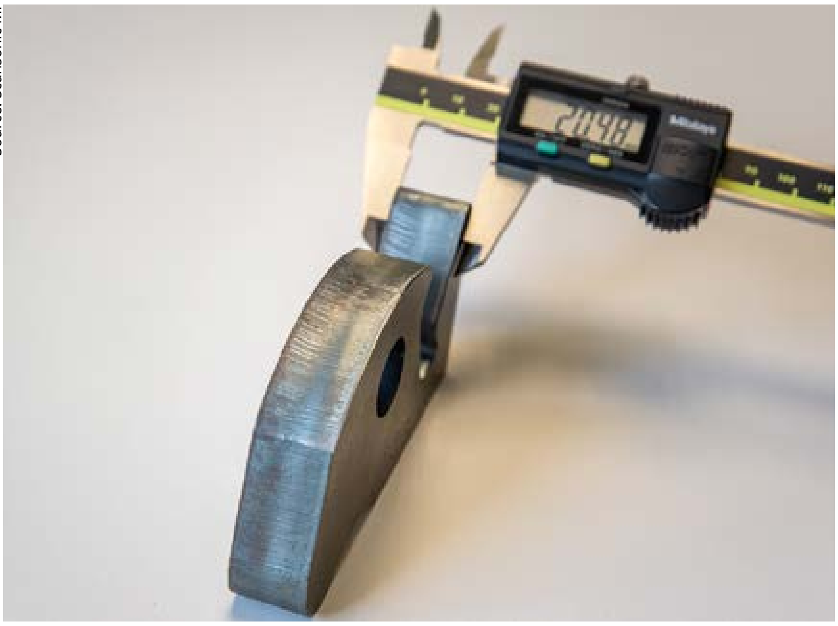
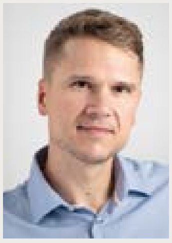


Fig. 4 Higher laser power levels permit easy cutting of even thicker sheet metal – an interesting alternative to plasma cutting

Author



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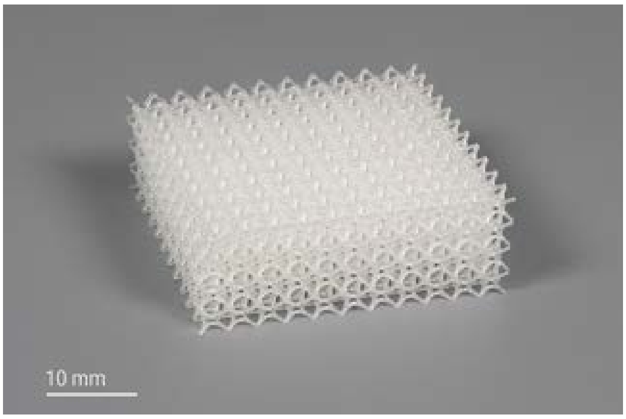
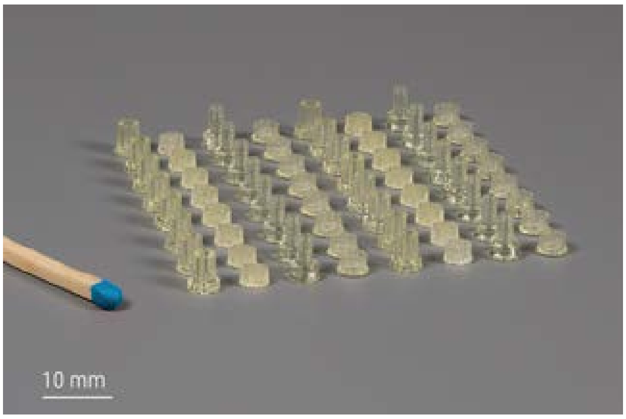
3D microfabrication up to the centimeter scale

Nanoscribe's 3D microfabrication range expands to the macroscale while maintaining particularly complex structures and filigree details



The new XLF Print Set speeds up the production of voluminous centimeter-sized objects. Shown in the picture: highly filigree scaffold cube of 32 × 32 × 12 mm³, printed overnight. (Source all images: Nanoscribe)



With the new XLF Print Set many millimeter-sized parts with complex structures and fine details can be produced in one pass. Shown in the picture: 64 different micromechanical parts, all printed in one pass, each with a diameter of about 4 mm.

Two-photon polymerization (2PP) is a well-known 3D printing technology for high-precision microfabrication. However, until now, 2PP was limited to object sizes of just a few millimeters. Nanoscribe has introduced new capabilities that now extend high-precision 3D printing performance to centimeter-sized objects.

Two-photon polymerization is proven to be at least a hundred times more precise than comparable AM technologies such as high-resolution SLA and DLP or projection micro-stereolithography (PµSL). One of the main factors that affects the precision in 3D microfabrication is the inherent principles of 2PP which makes use of a photopolymerization that occurs only at the tight laser focus point. The small feature sizes achieved with this technology extend far into the sub-micrometer range. This makes 2PP-based 3D printers suitable for the production of high-resolution and filigree structures with complex geometries. Smooth surfaces, for example for micro-optics, can reach surface roughness of below 10 nm R_a. These capabilities exceed what conventional AM technologies have to offer.

Nanoscribe recently presented a completely new solution for macroscale parts with centimeter dimensions while maintaining 3D design freedom, high precision and filigree details. Combined with new generation 3D printers, the XLF Print Set for extra-large features expands the manufacturing range of nano and microscale structures to millimeter and centimeter-sized objects. At this scale, the precision is typically two to five times higher than comparable microfabrication technologies.

The new capability allows 3D-printing based on two-photon polymerization to close the gap with high-resolution DLP and PµSL. What is more, the new print set provides a much higher volume throughput so that voluminous millimeter and even centimeter-sized objects can be manufactured in batch processes for the first time. Objects up to 30 cm³ can be produced in a single pass.

Quantum X shape belongs to Nanoscribe's new generation of 2PP-based 3D printers. The printer is intended for 3D microfabrication at four different scales with a total of four different print sets, covering the scale range from submicron, micro, millimeter to centimeter scale. Each print set combines precision optics, printing materials and software, matching each other to enable straightforward printing preparation, execution and results. Thanks to the printer's straightforward processes and workflows, high-precision 3D printing becomes less error prone and more reproducible, also for beginners. As a consequence, design iteration cycles drastically shorten to accelerate rapid prototyping and entire industrial manufacturing processes.

The new XLF print set contains an air objective lens that offers an increased print field of up to 3,200 µm in diameter and a relatively large working distance of 18.5 mm. Combined with a high laser scanning speed, adjustable voxel sizes and printing parameters, and a highly sensitive photopolymer resin, the print set provides a comprehensive solution for high-precision 3D printing in the millimeter and centimeter range. The new capabilities address the needs of prototyping and manufacturing, for example of mechanical parts such as connectors, housings or gears, microfluidic structures such as nozzles, and many more products. Thanks to the high-precision capabilities of the new print set, lattices and mesh structures with centimeter dimensions can also be printed while maintaining the filigree additive manufacturing offered by two-photon polymerization.

www.nanoscribe.com

Quantum X shape is Nanoscribe's new generation 3D printer based on two-photon polymerization for rapid prototyping and wafer-scale batch production of virtually any 2.5D and 3D shape, from the submicron to centimeter scale.

When a laser collar tames the arc

Hybrid technology developed and built for DVS research project 'KoaxHybrid'

Fraunhofer ILT engineers have developed a new optical system with glass substrates and an arc torch which unites gas metal arc (GMA) welding and laser material deposition with an annular beam, thus creating a completely new process that combines the best of both worlds: two different additive processes with wire-shaped filler material. We are talking about wire arc additive manufacturing (WAAM) and wire laser material deposition (WLMD). Both processes have system-related advantages and disadvantages: compared to WAAM, WLMD is costly, has low deposition rates, but is characterized by low heat input and precise layer buildup exactly at the desired location. For this reason, it is particularly in demand in the aerospace industry. If a higher application rate is required, WAAM is the better choice, whereby the achievable surfaces are wavier and the layer buildup is significantly coarser.

In joining, the combination of laser beam welding and gas metal arc welding is established under the name LB-GMA hybrid welding. However, this lateral process is direction dependent and only suitable to a limited extent for joining three-dimensional seams.

When the processes are combined coaxially, the deposition rate can be increased by up to 150 percent, so that the new direction-independent 3D printing process can also be used for large components. "Because the surface waviness decreases, the amount of post-processing required is significantly reduced compared to the WAAM process," explains Max Fabian Steiner, a research associate at Fraunhofer ILT.

In the hybrid process, the arc between the end of the wire and the substrate is enclosed by the annular laser radiation, as if by a collar. The idea behind this combination is that the arc cannot break out of this collar and is forcibly guided. The new process owes its name, COLLAR Hybrid, to this 'forced guidance', whereby the acronym COLLAR refers to the common coaxial laser arc of the two processes.

Source: Fh. ILT, V. Lannert

The new COLLAR hybrid additive manufacturing process relies on a combination of arc and laser deposition.

While Fraunhofer ILT is using the new system technology to further develop metallic 3D printing with annular-shaped laser beam and arc technology, the RWTH Aachen University Institute for Welding and Joining (ISF) is using it to develop direction-independent hybrid welding with ring focus and coaxial wire feeding.

www.ilt.fraunhofer.de

Two additive manufacturing processes in comparison

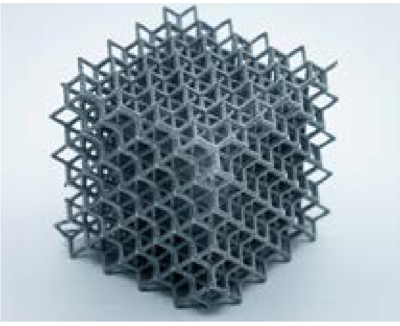
Automated solutions for powder preparation and feeding

A team from the center for additive manufacturing at Fraunhofer IPA evaluated the technical and economic potential of selective absorption fusion versus selective laser sintering.

The two additive production processes are similar: in selective laser sintering (SLS), a plastic powder such as polyamide 12 (PA12), is applied to the surface, heated and then selectively solidified with a laser beam. This process is repeated layer by layer.

The selective absorption fusion (SAF) process uses similar plastic powders. However, the process differs from SLS in terms of the solidification mechanism of the powder: after the powder is applied for each layer, inkjet print heads in SAF apply an ink that absorbs infrared radiation in specific areas so that the powder heats up after an infrared emitter passes over it and fuses together.

One possible advantage of this process is the time saved. Instead of deflecting a laser beam in many individual paths per layer, SAF technology requires only a single pass of the print heads and infrared lamp. The build time per layer is therefore not dependent on the components to be printed. However, SLS and SAF have not yet been systematically compared. This benchmark is now being carried out by a research team led by Patrick Springer from the center for additive production at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA. The industrial partner is Götz Maschinenbau, a 3D-printing service provider.



Source: Fh. IPA, J. C. Janhsen

Test sample produced with selective absorption fusion

The team now wants to investigate above all the lines of freedom and limitations in the comparison of the processes to each other. To this end, standardized test construction jobs for predefined test scenarios will be printed and evaluated for both processes. The researchers are using PA12, the standard material for 3D printing with plastic powders. Fraunhofer IPA is one of the first research institutions in Europe to use a Stratasys H350 system, which can process thermoplastic powders from various suppliers, to manufacture the test components.

In order to exploit the full potential of SAF technology, Fraunhofer IPA is also researching automated solutions for powder preparation and feeding. "We support industrial users in the implementation of the technology up to the production of series components. In addition to the application-specific qualification of the process itself, we also take a close look at the overall industrial process chain," says Springer.

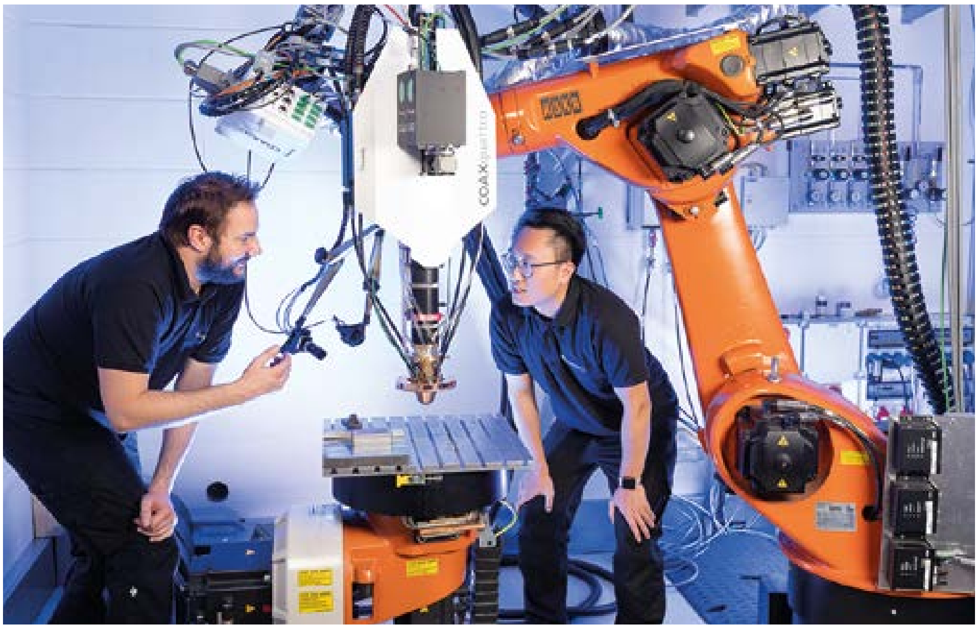
www.ipa.fraunhofer.de

Resilient laser cladding with high-power laser

Fraunhofer IWS develops efficient, fast, and sustainable coatings for industrial components

Together with its project partner Laserline, the Fraunhofer Institute for Material and Beam Technology IWS has developed applications and specific processes for this laser class to industry readiness under the label "HICLAD".

High-power diode lasers with outputs of ten or more kilowatts open new application scenarios for laser cladding. Particularly sustainable and resource-efficient coatings can be produced and applied, for example in automotive, machine construction, and other industries. A high feed rate, optimal speed, and a large spot: Fraunhofer IWS has been developing the HICLAD process family for laser cladding for several years to enable customized solutions for highly productive coating processes using high power diode lasers. To this end, the researchers are, among other things, fine-tuning the parameters of energy distribution, speed, and feeding rate in such a way that wide process windows become possible and fluctuations in the production process become tolerable.



A laser beam runs through the center of the nozzle, around which up to eight separately controllable channels feed wires and powders. (Source: Fh. IWS / ronaldbonss.com)

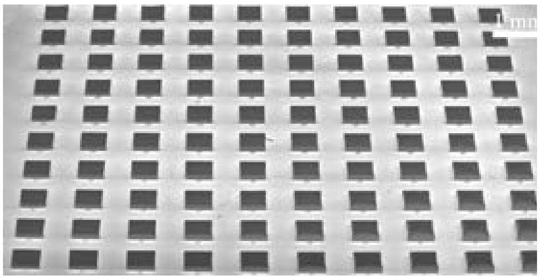
The Dresden-based institute and the Laserline company have now achieved and surpassed deposition rates with 20-kilowatt diode lasers that were previously only feasible using plasma-transferred arc processes (PTA). The partners have also made considerable progress compared to existing laser-based solutions: depending on the specific material and the nozzle selected, HICLAD achieves deposition rates of 18 kilograms per hour in industrial use. For an Inconel 625 nickel alloy, for example, productivity can be roughly tripled compared to a solution using a conventional 9 kW laser. The exact values depend on the specific application scenario. Compared to competing solutions with high-power lasers, the Fraunhofer IWS process is considered more robust.

In contrast to powder-based laser cladding, wire-based processes were previously limited to a maximum of six kilowatts. COAXquattro now enables laser power of up to 20 kW to be used in the combination of wire and powder. This can play a decisive role in multimaterial development, for example of novel alloys. Different materials can be fed as required through each of four wire and powder channels. In addition, the comparatively short processing times reduce the costs for staff, shielding gases and other operating costs. In general, the system is designed for particularly efficient material utilization as well as very robust and flexible process control with high quality.

www.iws.fraunhofer.de
www.laserline.com

Better control in additive manufacturing

New approach to optimize elastic parameters of two-photon-polymerization fabricated structures



SEM micrograph of a cuboid parameter sweep fabricated via TPP. (Source: S. Schweiger et al.)

Additive manufacturing (AM) using two-photon polymerization lithography (TPP) has increased in usage in both industry and research. Currently, a major constraint of TPP in general and specifically of the material IP-Q from Nanoscribe, Germany, is the users' limited access to knowledge about material properties. Due to the nature of the process, the elastic properties in particular depend not only on the utilized material but also on structure size, process, and fabrication parameters. For example, no degree of conversion (DC) and Young's modulus (E) values for IP-Q had been reported up to now.

AM via TPP is based on selective curing of a liquid precursor to create solid structures inside a drop of monomer. Afterwards, the leftover liquid is washed away. Well known TPP applications are optical sub-micron structures, where the photoresist IP-Dip is commonly utilized. The more recently developed photoresist IP-Q was designed by the same manufacturer for larger applications, e.g. mounts, molds, and structural metamaterials. Sample structures from each of the two photoresists were produced in parameter sweeps. This allows the comparison of process parameters to the resulting characteristics with Raman spectroscopy. The characteristic peaks of the Raman scattering spectrum can be used to identify chemical substances. In a recent study, it was used to determine the ratio of monomer to polymer – or DC – in the TPP samples. Micro and nanoindentation were used to test the mechanical properties of the samples. A hard tip whose mechanical properties are known is pressed into the sample whose properties are unknown. E values were computed from the slope of the load vs. displacement curve.

Finally, parameter sweeps of cuboid sample structures fabricated using TPP were investigated across the laser power and scan speed parameters to find dependent properties.

"A promising application for this method is the characterization of the elastic parameters of acoustic metagratings and metamaterials fabricated on MEMS," said Severin Schweiger of Fraunhofer Institute of Photonic Microsystems and Brandenburg University of Technology in Germany. (Source: SPIE)

Reference: *S. Schweiger* et al.: Characterization of two-photon-polymerization lithography structures via Raman spectroscopy and nanoindentation, J. Opt. Microsyst. **2**, 033501 (2022); DOI: 10.1117/1.JOM.2.3.033501

www.ipms.fraunhofer.de

Fiber as a Bessel beam generator

New device for applications in imaging, optical trapping and communications

An all fiber-based approach to generating Bessel beams could open up new applications in imaging, optical trapping and communications. Bessel beams possess several interesting properties including self-healing, diffraction-free propagation and the ability to carry orbital angular momentum (OAM). This family of vortex beams with a characteristic ring-like shape and a dark central region include different orders of beams carrying different values of OAM.

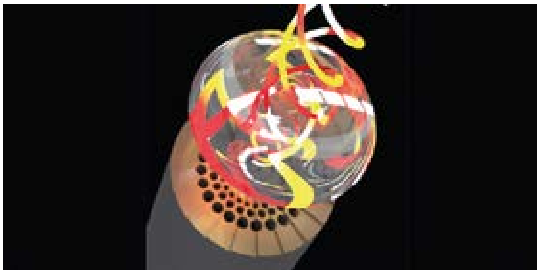


Illustration of a custom-engineered optical fiber to generate Bessel beams, fabricated using two-photon lithography. (Source: A. Bertoncini, Kaust)

However, the creation of Bessel beams is somewhat inconvenient: several bulk optical elements, such as spatial light modulators or cone-shaped axicons, are needed to convert Gaussian beams to Bessel beams. Now, Innem Reddy, Andrea Bertoncini and Carlo Liberale from King Abdullah University of Science and Technology in Saudi Arabia have experimentally demonstrated that a custom-engineered optical fiber can do the job and generate a particular Bessel beam on demand. "By opting for a fiber-based solution, we can obtain a compact Bessel beam generator that is pre-aligned and can deliver these beams even in remote and confined spaces, such as endoscopic applications," explains Reddy.

"In particular, the fiber-based generation of Bessel beams allows innovative applications, such as minimally invasive endoscopic probes, optical coherence tomography, fiber-based optical trapping and manipulation of microscopic particles." The team's fiber is a masterpiece of custom engineering. They use two-photon lithography (TPL), which enables 3D printing of intricate optical structures to fabricate special beam-shaping elements directly onto the tip of a single-mode optical fiber. Their design has three segments that, collectively, efficiently align and transform a conventional Gaussian beam into an annular beam and then, finally, a Bessel beam of the desired order and OAM value.

The team has already used TPL to customize fibers in other ways, including the creation of polarization beam splitters, microlens assemblies and optical tweezers. "Fabricating ever more sophisticated optical devices on the end of optical fibers to empower them to deliver complex functionalities is one of the main research directions of our group," commented Liberale. (Source: KAUST)

Reference: *I. V. A. K. Reddy* et al.: 3D-printed fiber-based zeroth- and high-order Bessel beam generator, Optica **9**, 645 (2022); DOI: 10.1364/optica.453839

https://bese.kaust.edu.sa

3D printing of organic electronics

Researchers achieve microscale organic electronics using multiphoton 3D printers

Over the past few years, 3D printing of electronics has become a promising technology due to the potential of applications in emerging fields such as nanoelectronics and nanophotonics. Among 3D microfabrication technologies, multiphoton lithography (MPL) is considered the state-of-the-art amongst the microfabrication methods. It has true 3D fabrication capability, an excellent level of spatial and temporal control, and the versatility of photosensitive materials mostly composed of acrylate-based polymers/monomers or epoxy-based photoresists. When looking at the future of production of microscale organic electronics, Mohammad Reza Abidian at the University of Houston Cullen College of Engineering sees their potential for use in flexible electronics and bioelectronics, created by multiphoton 3D printers.

"We introduced a new photosensitive resin doped with an organic semiconductor material (OS) to fabricate highly conductive 3D microstructures with high-quality structural features using the MPL process," Abidian said. This showed that the fabrication process could be performed on glass and flexible substrate poly(dimethylsilosane). It demonstrated that loading as low as 0.5 wt % OS into the resin greatly increased the electrical conductivity of printed organic semiconductor composite polymer by over ten orders of magnitude. "The excellent electrical conductivity can be attributed to the presence of OS in the cross-linked polymer chains, providing both ionic and electronic conduction pathways along the polymer chains," Abidian said.

To demonstrate the potential electronic applications based on the OS composite resin, his team fabricated various microelectronic devices, including a micro-printed circuit board, which comprised various electrical elements, and an array of microcapacitors. Three dimensional bioprinting of organic semiconductor microdevices based on MPL has potential in biomedical applications including tissue engineering, bioelectronics, and biosensors. Abidian's team successfully incorporated bioactive molecules such as laminin and glucose oxidase into the OS composite microstructures (OSCMs). To confirm that the bioactivity of laminin was retained throughout the entire MPL process, primary mouse endothelial cells were cultured on OS composite microstructures. Cells seeded on laminin incorporated OSCMs displayed evidence of adherence to substrate, proliferation, and enhanced survival.

Reference: *O. Dadras-Toussi* et al.: Multiphoton Lithography of Organic Semiconductor Devices for 3D Printing of Flexible Electronic Circuits, Biosensors, and Bioelectronics, Adv. Mat. **34**, 2200512 (2022); DOI: 10.1002/adma.202200512

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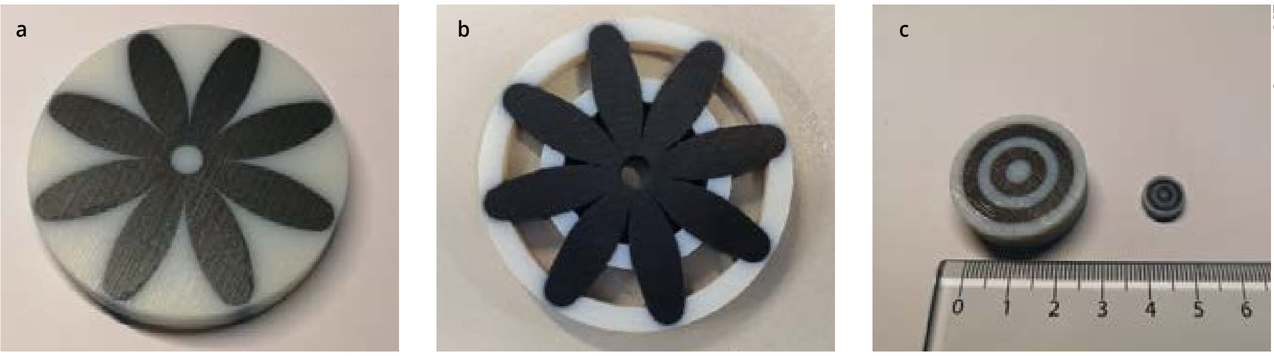
Full article now online and in PhotonicsViews issue 1/2023 **Preview**

GRIN pad polishing

3D-printed hardness-gradient polishing tools for micro-optics synchrospeed polishing



Source: OST

Novel GRIN polishing pads for synchrospeed polishing are currently under investigation: (a) a full material synchrospeed polishing pad (b) a lightweight synchrospeed polishing pad and (c) a special, full material synchrospeed polishing pad in two dimensions for lens diameters of 9 mm and 4 mm. Smaller pad dimensions are currently under investigation.

A new concept for CNC polishing pads is presented, the gradient index lens (GRIN) pad polishing tools. Instead of gluing polishing foils as a layer onto metallic tool holders that have the spherical surface to be polished, 3D-printed GRIN pads are applied directly to the CNC tool axis. The hardness gradient printed into the GRIN pad eliminates the need for metallic spherical tool holders, replaces the laborious cutting and cementing of polishing foils, and potentially enables a synchronous polishing process for sub-millimeter optics. An initial experimental study is presented demonstrating the GRIN pad concept and showing its feasibility for synchrospeed polishing of micro-optics.

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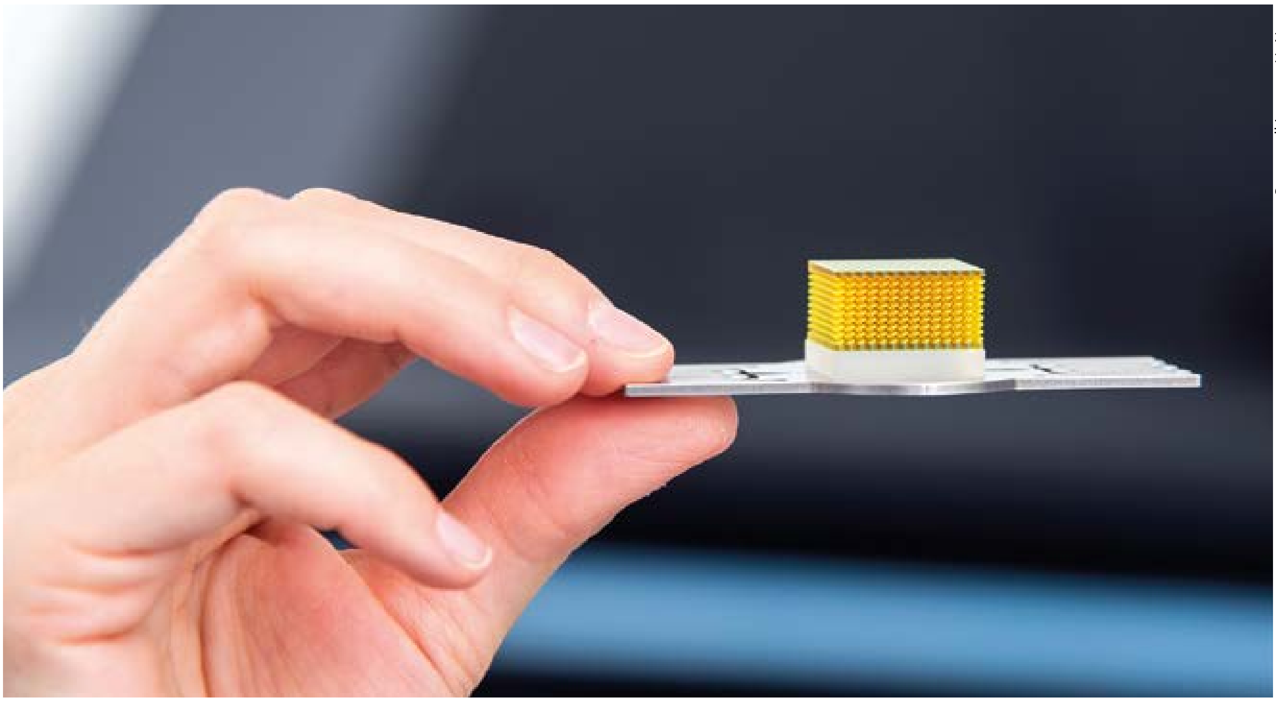
https://doi.org/10.1002/phvs.202200042

Software integration for 3D lens prototyping and complex lens analysis workflows

Ansys Zemax solutions enable rapid prototyping and yield optimization for UpNano's in-house and external projects



Source all images: UpNano

UpNano combined their additive manufacturing system NanoOne with Ansys Zemax' virtual prototyping technologies to help companies optimize polymer lens development and achieve high-resolution precision at an unprecedentedly tiny scale. The high-powered lasers and data-driven system design enhancements yielded rapid fabrication techniques at the nano, micro, meso, and macro range.

▲ With the vat mode UpNano has laid the foundation for the batch and series production of 3D printed plastic micro-components.

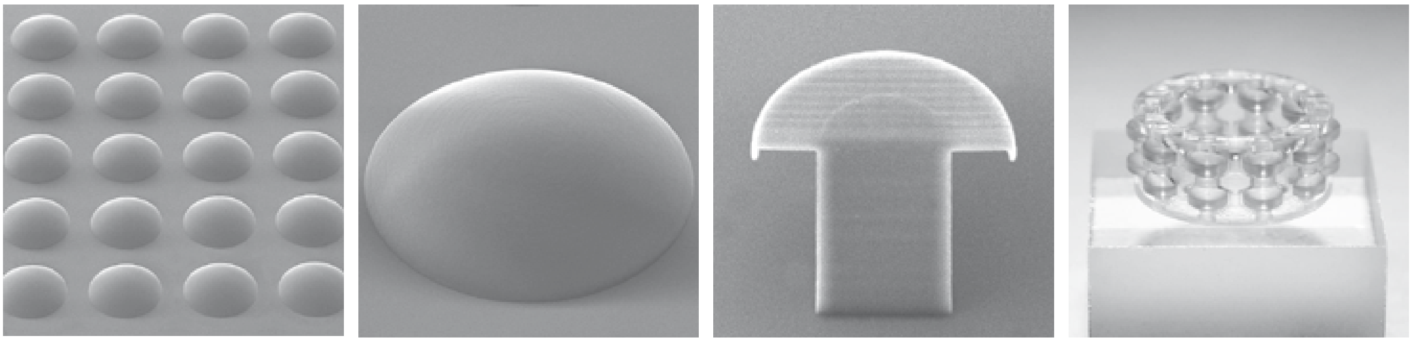
The market is booming for optical technology. Manufacturers in industries like consumer electronics and optical sensor-based medical diagnostics are seeking new ways to gain competitive advantage. The faster they can reach the market with viable, high-quality products that meet the ever-expanding range of consumer expectations, the better their chance to survive and thrive.

Winning this race to the market means finding strategic ways to get insights from reliable data, apply the latest technologies, boost innovation, and minimize production cycles without sacrificing quality. Vienna-based UpNano helps its customers in exactly this space, furnishing them with technology and analysis that accelerate optical product development while also enabling decision guidance for developing simple polymer lenses versus more complex freeform or aspherical varieties.

Ansys Zemax OpticStudio gives UpNano the power and flexibility to rapidly design and build optical systems for the resale market, and enable its customers to do the same. "Aspherical lens production can be very expensive, but with polymer optics, production costs are the same for spherical and aspherical surfaces," said Peter Gruber, UpNano co-founder and head of technology. "With OpticStudio, we can efficiently design both lens types in-house."

Speeding productivity with 3D-printed lens prototypes

At the heart of these efficiency gains is UpNano's ability to incorporate 3D printing capabilities that match the current market demand for hyperminiaturization. The company's 3D printing



Microlenses, surface elements, or roller bearings can be produced with two-photon lithography across 12 orders of magnitude. Here: micron range.

technologies enable UpNano and its customers to quickly produce prototypes they can use for validating optical system designs, in lieu of spending the considerable extra time and money required to manufacture lens prototypes using traditional methods.

This iterative prototyping process using 3D printing saves companies time and money while improving design quality by tracking to engineers' design ideas at the speed of their creativity. Rather than waiting a few months to get a prototype, they can quickly 3D print a model, discover the impact of their latest changes, and go right back to generating the next series of improvements to their product designs.

Planning the best design approach with reliable, accurate data

Another important use of OpticStudio for UpNano is to test the technology transfer of going from a multispherical lens design to a single, complex aspherical approach. For some companies, the redesign opportunity makes financial sense, but for others, it doesn't or they're not sure.

Using virtual prototyping capabilities in OpticStudio, UpNano tests various designs and advises its customers on manufacturability of their optical solutions with simple versus complex lenses. By calculating the relative costs and production times of the different lens type configurations to meet each customer's requirements, UpNano empowers its customers with real data that can guide their approach to achieving a final product.

"The return on investment of buying one of our tools can be realized by most companies within a few months – basically three to four customer jobs," said Henrik Åkesson, UpNano head of global sales. "To achieve this advantage, however, they need evidence that our approach can be successful in their specific use case. For that, we provide them with a prototype so that they can generate a full set of comparative analysis data enabling the best decisions about their ultimate design."

Spearheading a new venture with Ansys Zemax technology at the core

UpNano has its roots in an academic project Gruber led at the Technical University of Vienna, within Aleksandr Ovsianikov's research group, where he spent over ten years working alongside other scientists on photon polymerization solutions for the bioengineering, biomedical, and manufacturing industries. In 2018 he left the TU and together with his co-founders, took the lead in spinning off the project into a commercial venture, and UpNano was founded. The first customers were TU Vienna and the Medical University of Vienna.

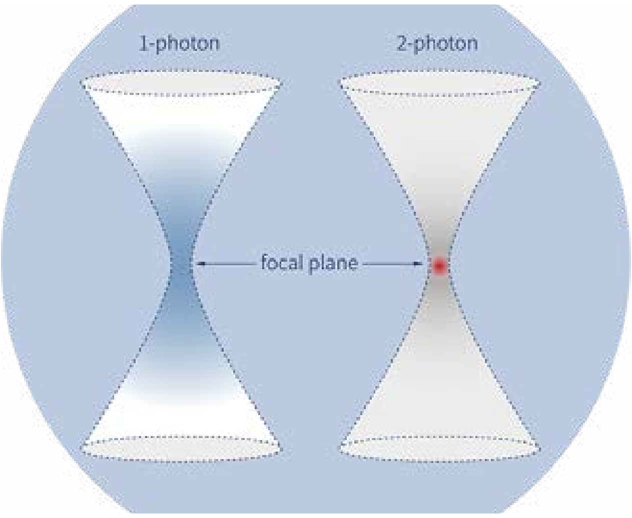
Following the launch of the NanoOne and the commercialization efforts, UpNano began taking a steady stream of orders for its technology and services, delivering to both academic and industrial organizations. "We're just now starting to gather the results from our initial customers' projects," said Akesson. "All indications are that our technology is helping them get to market faster with highly innovative products. At the heart of it, we're using OpticStudio to streamline our own manufacturing and to guide the data-driven consulting we provide on manufacturability."

Gruber first worked with Ansys Zemax software when creating a trial project for TU Vienna. The results were successful for generating a viable starting point for UpNano's lens designs.

"We needed a solid solution that was trustworthy and well-known throughout our target market," said Gruber. "Our partners were all using Ansys

"Ansys Zemax is helping us drive the innovation and feasibility of manufacturing multifunctional diffractive lenses in place of the typical refractive stacks. Gaining the advantage of timing in this space will have a huge impact on our role throughout this industry."
Henrik Åkesson
head of global sales
UpNano

Company



UpNano's high-resolution 3D printing system is based on 2-photon polymerization (2PP), which allows highest resolution in the sub-micrometer range. The 2PP technology takes advantage of the spatial selectivity of 2-photon absorption (2PA). The 2PA probability significantly reduces beyond the focus point, thus also the fluorescent volume is lowered, resulting in higher spatial resolution.

Zemax already, and we could easily see ways of further optimizing our processes beyond what we accomplished for those first few customers."

That left a key open question: Should UpNano outsource its optical design to an Ansys Zemax-trained third-party consultant, or develop OpticStudio knowledge in-house? Ultimately, the best answer was for Gruber to purchase a license and learn the product himself. With two weeks of onboarding assistance from Ansys Zemax and access to the Ansys Zemax knowledge base of articles and self-paced tutorials, he spent between two and three months learning the software and further optimizing UpNano's nascent optical design and manufacturing workflows.

As a result, he saved a great deal of time that it might have otherwise spent finding an optical design consultant, acclimating them to UpNano product and business philosophies, and combining the consultant's outsource efforts into UpNano's master plan. "By doing the optimizing in-house, we saved a great deal of time and money," said Gruber. "Normally a project the size of our typical ones would require a minimum of three optical engineers. Using Ansys Zemax, he was able to do the whole thing himself end-to-end for our internal solution. This approach gave us a considerable head start on our business momentum, and it also gave us solid in-house knowledge for future development."

Optimizing design and manufacturing with a few key tools

Several OpticStudio capabilities drove ongoing refinement of design workflows at UpNano during the company's early months. Using inputs available in OpticStudio, UpNano minimized the impact of potential fabrication errors on lens performance, including errors with lens geometry and in the refractive index. This in turn increased UpNano's manufacturing yield, because the software enabled them to rule out design approaches that couldn't withstand the necessary tolerancing conditions. UpNano also used built-in OpticStudio features to calculate manufacturing costs.

"By using OpticStudio to optimize our manufacturing yield, we iterated our project cycles far more quickly, and came up with accurate estimates for materials usage," said Gruber. "We also discovered ways to input the optimizations directly for tolerance parameters, and as a result, we could get the yield data we needed within a few minutes or hours rather than waiting days."

Another helpful capability was the Hammer Optimization feature, which performs repetitive optimization tasks across multiple design iterations and tries out new material permutations or other design alternatives exhaustively until the user has a clear set of options to choose from.

Into the future of optics and 3D-based miniaturization prototyping

OpticStudio continues to play a central role in UpNano operations, and the team looks forward to a continued collaboration with Ansys Zemax as its key optical design for manufacturability and overall optics industry thought leadership partner. Among other projects, UpNano is currently seeking ways to add the correct material properties such as refractive indices it has developed into Ansys Zemax material libraries so that UpNano and its customers can accurately calculate optics more easily.

"The market for optical technologies continues to thrive, and the faster we can help get our products and our cus-

Company

UpNano

UpNano is a system provider for high-resolution 3D printing. In addition to the development, production and manufacturing of printing systems and the corresponding operating software, UpNano offers printing materials and accessories optimized for the process. Quality and environmental awareness are two fundamental prerequisites which are reflected in the ISO 9001 and 14001 certifications of the company.

www.upnano.at

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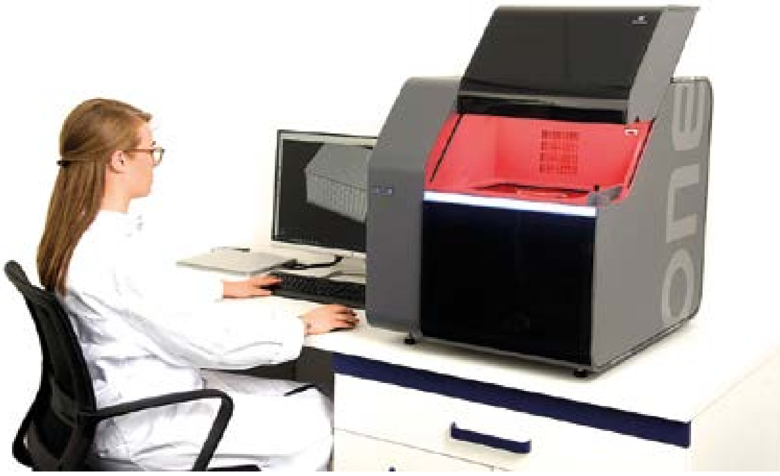

NanoOne is the fastest high-resolution 3D printing system on the market. It is based on multiphoton lithography and combines the precision of 2-photon polymerization with an unmatched throughput of >450 mm³ per hour. This makes the system suitable not only for scientific research approaches and multi-user facilities but also for the batch and small series production of industrially applied microparts.

tomers' products to market, the more competitive advantage we're going to achieve," says Akesson. "In particular, Ansys Zemax is helping us drive the innovation and feasibility of manufacturing multifunctional diffractive lenses in place of the typical refractive stacks. Gaining the advantage of timing in this space will have a huge impact on our role throughout this industry."

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How micro-AM is impacting time-to-market for precision plastic parts

Reducing product development costs and stimulating design optimization – three case studies

Source all images: Accumold

Microgears made using the Nano-Dimension Fabrica 2.0 micro-AM machine. The smallest gears shown have 20 teeth contained on a wheel diameter of 1.25 mm, each tooth measuring 100 µm.

Some thirty years ago now, additive manufacturing (AM) — which back in the day was more typically known as rapid prototyping — disrupted (as the name suggests) the prototyping stage of product development. Now, it targets the reign of micromolding.

The ability to print parts in three dimensions from CAD solid models facilitated concurrent engineering, as within days of a design being complete, all relevant product development departments could sit together analysing an accurate prototype, and designs could be easily re-iterated to overcome potential downstream manufacturing issues. For a tooling manager to be able to initiate changes in product designs to streamline the tooling process a few days into the development of a product knocked weeks if not months off product development cycles.

Move on 25 years, and AM began disrupting the traditional manufacturing paradigm once again, this time in the area of production. In general terms, AM technologies have become increasingly sophisticated over time, and the precision and accuracy of builds in a variety of materials means that AM is now challenging legacy manufacturing processes in terms of speed, cost, and tolerance attainment.

This history of AM over the last thirty years, however, is only really accurate when looking at the production of macro-sized parts and components. It is only in the last few years that AM has been able to disrupt the area of micro-manufacturing, as it is only in the last few years that innovators have managed to refine the AM process to achieve the micron level tolerances and surface features that have been the preserve of legacy production processes such as micromolding for decades.

Today, however, micro-AM processes like the Fabrica 2.0 from Nano Dimension that are used at Accumold can now additively build parts and components only previously possible through the use of micromolding, and can do so in a way that allows manufacturers to completely re-imagine the way that precision micro parts and components are made, and which changes the basic economics of manufacturing.

The Fabrica 2.0 can attain 1.9 micron resolution in X and Y, and the technology builds additively in 1 – 5 micron layers. With this breakthrough, the path to the creation of innovative miniaturized parts at amazing speed and reduced cost is open for all industry sectors.

What does this mean for manufacturers?

The Fabrica 2.0 micro-AM platform promotes innovation, and stimulates cost and time-to-market reductions. But in general terms, success through the use of the Fabrica 2.0 is measured in microns and hours. Micron-level detail can be

Impellers made using the Nano Dimension Fabrica 2.0. They are used to increase pressure and flow rate of a fluid, and measure 5.66 × 5.66 × 2.87 mm

The Nano Dimension Fabrica 2.0

achieved without the need to fabricate tools, and this means that you can have intricate and geometrically complex prototypes in a matter of hours.

There is a limit to the ability to create complicated parts using traditional micro tooling. With increased complexity comes increased cost, but not when using the Fabrica 2.0 micro-AM technology. The absence of the requirement for a physical tool enables design engineers to think out of the box and attain previously unimaginable design goals. This design freedom coupled with the inherent manufacturing agility that is a core characteristic of AM require a root and branch re-assessment of all aspects of the product development process, a disruption that will stimulate future product successes and enhanced market-share and profitability.

Workflow can be optimized by using the Fabrica 2.0 because it produces less scrap and requires fewer tools than conventional manufacturing processes. It also promotes the reduction of iterative processes, assembly, and inventory. This means that significant operational cost benefits are now attainable at the micro-manufacturing level.

Through a combination of design optimization and improvements in materials, direct rapid soft tooling (DRST) can now be additively manufactured and used to injection mold real parts. This unlocks new business possibilities for mold makers and manufacturers who , up until this point, have been restricted to the use of long lead time and expensive traditionally manufactured mold tools to achieve any volume of molding, from prototype runs all the way through to mass manufacture. The business case for a process chain that includes DRST, with dramatically shorter lead times at reduced cost is obviously compelling.

Real time case studies

At Accumold, we use micro-AM as a tool to reduce the time from initial design to market. When looking at a conventional prototyping scenario, prototype tooling needs to be fabricated at often considerable cost, and also taking upwards of six weeks, meaning that initial testing cannot take place until at least week 7 of a product development process. The time involved when using conventional tooling is only exacerbated if (as is often the case) design changes are required, and tooling needs to be modified.

When using micro-AM, a design can already have been refined numerous times by week 7 as the process requires no traditional tooling, just DRST. This means that time and focus in this early stage of product development can be spent on design optimization, and so micro-AM not only saves time and cost in product development, but it also stimulates innovation.

The theoretical case for the use of micro-AM in precision plastics part and component development is therefore extremely compelling. However, Accumold now has significant experience in using the technology for customers, and so we are able to illustrate the way in which micro-AM has benefitted OEMs in real time.

Due to confidentiality issues related to the case studies discussed below, we are unable to include pictures of the products discussed. Pictures used in this article are non-related part shots that show the precision and resolution that can be achieved using the Fabrica 2.0 technology.

Case study 1 – intraocular implant

Our first example is a medical OEM customer making an intraocular implant that measured 1.6 × 2.9 × 0.7 mm. The customer was up against a looming FDA submission deadline. The design included a small gap on one side of the part. While the rest of the part design was pretty much frozen, the customer needed to determine what size gap would be optimal considering that in its final assembly it would need to be accurately handled and safely implanted inside the eye.

Due to the micro size of this part, using the Fabrica 2.0 we could print a lot of samples in the 50 × 50 × 100 mm print envelope of the machine. We successfully printed multiple samples of six

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
DESIGN 1: Print and Test	DESIGN 2: Print and Test	DESIGN 3: Print and Test	DESIGN 3: Print Tool, Mold, and Test	DESIGN 4: Print Tool, Mold, and Test	DESIGN 5: Print Tool, Mold, and Test	DESIGN 5: Build Production Tooling			
DESIGN 1: Building Prototype Tooling						DESIGN 1: Mold and Test	DESIGN 2: Modify Prototype Tool		DESIGN 2: Mold and Test

A representation of how the use of micro-AM in a product development cycle can significantly reduce time to market which in itself reduces product development costs and stimulates design optimization.

A direct rapid soft tool made on the Fabrica 2.0 micro-AM platform

different designs for the customer to test. This took less than 24 hours to design, print, post process, package, and ship out to the customer, who was able to complete their testing in about two weeks. Their tests proved one of the designs superior to all others, and this was the design the company froze and submitted for FDA approval. Had we not been able to provide multiple part iterations for testing at one time the customer would have had to delay their FDA submission or choose a design without adequate test data. Once the customer is satisfied with their test performance Accumold can start to design and build the production tool so that we can qualify the tool and scale up to meet production volumes.

Case study 2 – implant tip

Another one of our medical device customers needed to finalize an implant tip design measuring 1.5 × 3.0 × 2.5 mm before the design freeze date. The customer needed a frozen design so that they could kick off tooling and not push out their overall project timeline. Using the Fabrica 2.0 we were able to print 16 different tip designs for the customer to evaluate. Again, we could print a lot of parts in the Fabrica 2.0 print envelope, and our first print included ten samples of each of the 16 design iterations. It took less than 24 hours to design, print, post process, package, and ship the parts to the customer, who completed their testing in a few weeks and came back with six different modified designs for another round of testing. Our second print was turned around in about one day so the customer could quickly resume testing.

Once all testing was completed, the customer sent us their frozen design. With that, we kicked off our mold manufacturing process with a DFM session to ensure the molded thermoplastic part would meet the quality and functional requirements defined by the customer. With project work starting a couple months prior, we already had an established line of communication with the customer so we could quickly design the production tool and production process understanding all the criteria that needed to be met.

Case study 3 – valve assembly

The last example comes from another medical customer who was trying to finalize the design of a valve assembly measuring 9.0 × 9.0 × 10.7 mm. This valve was comprised of a softer material overmolded on top of a harder machined part. The valve needed to maintain a seal while being rotated within the final assembly.

Our first batch of samples was molded in DRST with the Versaflex material. Testing found that a few dimensions were inaccurate, so the insert CAD models were updated, and new inserts printed a day later. The second round of samples worked better but we found the Versaflex was too rigid when rotating it in the test assembly. We then used the same printed inserts to mold parts in Sarlink. The Sarlink parts performed better in the test assembly, but some leakage was observed. Sources of the leak were identified, the CAD models were modified, and another set of inserts were printed. This final set of inserts produced valves that could be easily rotated in the assembly and did not leak.

From start to finish we were able to test three different DRST mold designs and two materials in about two weeks. The customer was extremely pleased with the results and was excited by how much we learned in such a short period of time.

Summary

All of the successful case studies discussed would not have happened without the Fabrica 2.0 micro-AM technology being used as a central tool in the product development process. Fundamental to the success of the Fabrica 2.0 is that it brings the benefits of AM to micro manufacturers for the first time, including hitherto impossible part complexity (enhancing design and functionality), no tooling costs, minimal set up costs, the ability to mass customise and personalise products, and the ability to produce DRST. As a versatile technology appropriate for prototyping, small batches, and potentially even mass manufacturing, the technology is now stimulating innovation in the micro manufacturing sector, and is truly changing the economics of manufacturing.

Company

Accumold

Accumold is the world's most experienced and largest micromolding innovator, and has grown to a 130,000 square foot fortified facility designed for assurance of supply. The company employs over 350 staff, and is a net exporter shipping all over the world every day from its Ankeny, IA, USA facility which runs 24 hours a day, 7 days a week.

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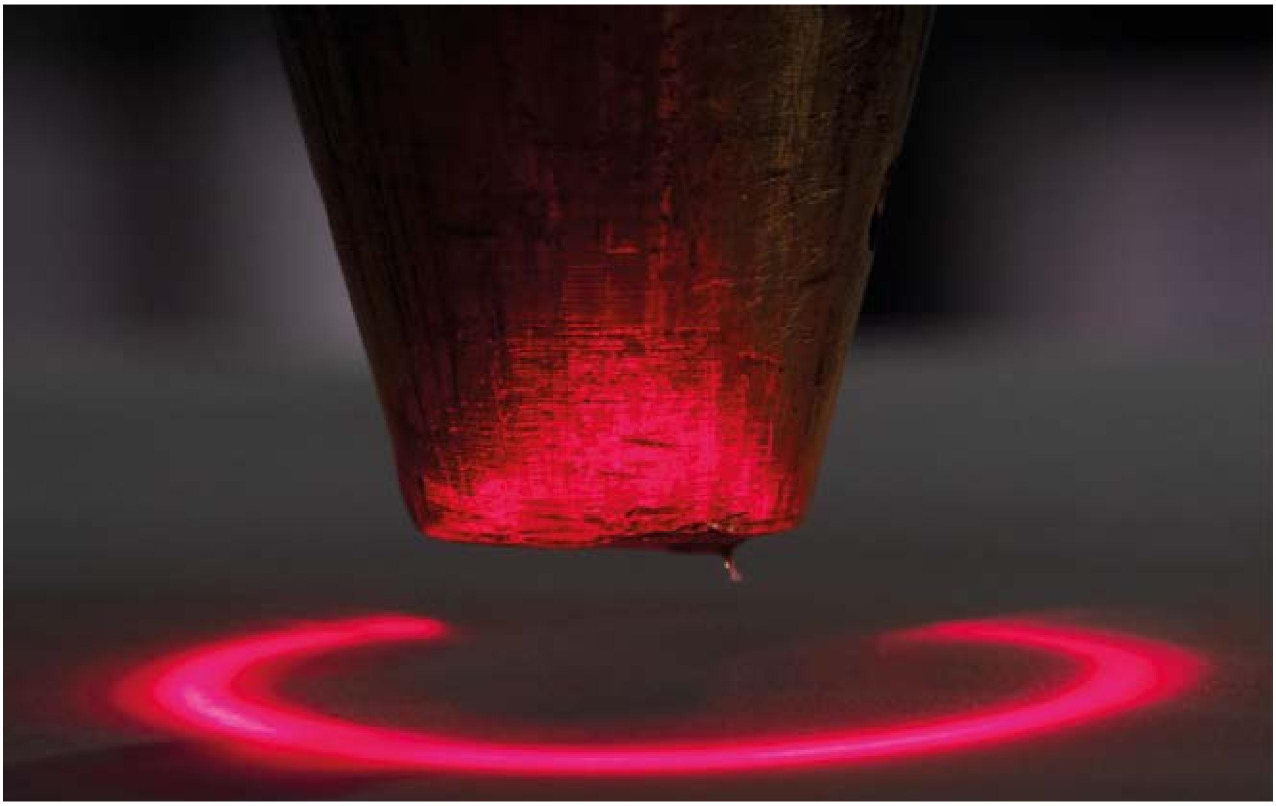
Hybrid additive manufacturing

Improved large scale additive manufacturing by means of laser tempering

Michel Layher, Jens Bliedtner, and René Theska



Source all images: EAH Jena

Large-scale additive manufacturing (LSAM) is an additive manufacturing process based on the principles of fused filament fabrication but with significantly higher material deposition rates. The novel hybrid process shown in this paper combines LSAM with a laser beam heat treatment. The structure and mechanical properties of parts are improved due to significantly decreased void sizes. The following article details investigations into the vertical and lateral remelting of strands as well as the utilization of a mirror system, which enables beam guidance according to the machine's printing path.

▲**Fig. 1** Achievable beam deflection at the circumference of the nozzle

Granule-based extrusion technology enables high mass output and enhances the variety of materials that can be used for strand deposition. Large-scale additive manufacturing (LSAM) in particular has been popular in industrial applications in recent years [1]. LSAM achieves results that are basically comparable to those of fused filament fabrication (FFF). However, due to larger nozzle diameters (1 – 3 mm) process-related voids occur in larger shapes. This leads to a more orthotropic part behavior and mechanical properties become strongly dependent on external load directions. To address this, not only process parameters are under constant optimization, but also new systematic improvements and hybrid approaches for the local heating of deposition paths are being considered in current developments.

Among them, laser beam heat treatment is known and has already been applied with FFF [2, 3], but applications in LSAM have not yet been investigated. A hybrid process, enhanced by a deflection system for dynamic beam guiding, appears to be very promising for part optimization in LSAM.

The novel hybrid, large-scale, additive manufacturing process combines the additive manufacturing technology of material deposition by a granule extruder with a unit for laser beam heat treatment. The principle is based on an FFF system consisting of a build plat-

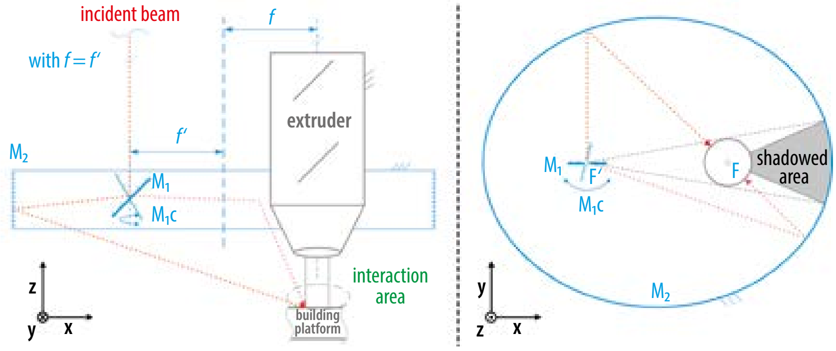


Fig. 2 Working principle of the elliptical mirror system, side view, with elliptical mirror as sectional view and top view in accordance with [6]

form and elevator, a feedstock supply, the emerging product and, if necessary, support structures.

Since polymers' absorption properties are wavelength-dependent, a carbon dioxide (CO_2) laser is used because its wavelength is well absorbed by all thermoplastic materials. Among them, styreneacrylonitrilecopolymer (SAN – TYRIL 790 – Trinseo) and poly(methyl methacrylate) (PMMA Altuglas VSUVT) have particularly suitable properties for remelting and polishing by a CO_2 laser beam treatment, as examined in unmodified raw material [4]. Those two polymer types were therefore selected for further investigation. The processing model applied was derived in [5]. It provides important characteristics of bead geometry generation and strand cooling so that the generation of stable and repeatable strand geometries is ensured. The laser beam needs to follow the strand deposition direction of the machine's manufacturing routine, so an appropriate optomechanical mirror system was designed. (Fig. 2) [6]. The design enhances LSAM through the combination of a rotating plane mirror (M_1) and an elliptical mirror (M_2). M_1 is located at one focal axis (F') of the elliptical mirror. The laser beam needs to strike coaxially on M_1, to be deflected into the other focal axis (F) by a rotation along M_1c. The laser beam is then directly aimed into the working area of the building platform.

The principle provides the potential to enable laser beam tempering in a huge area of the nozzle's circumference. Only a small area stays shadowed due to the extruder's diameter and is therefore not covered by the deflected beam.

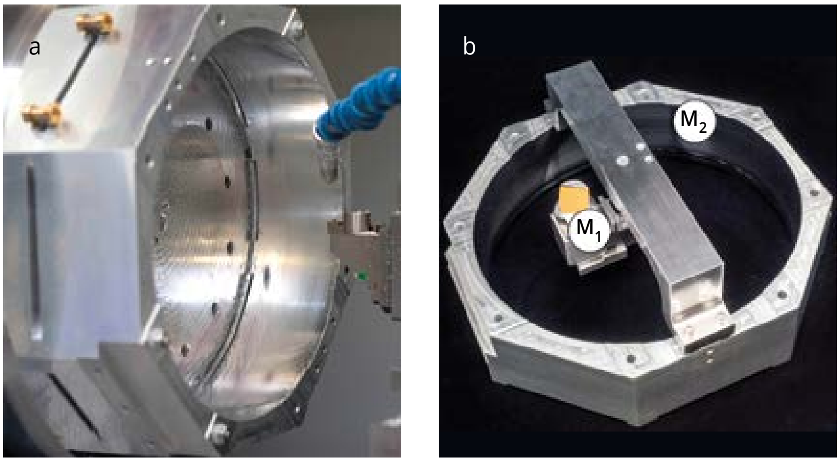


Fig. 3 Ultraprecision turning (a) and pre-assembled mirror system (b)

Manufacturing, preassembling and implementation of the mirror system

The elliptical tube-like mirror (M_2) and the associated rotating mirror (M_1) are individually designed, custom-made parts (Fig. 3b). Mirror surfaces are manufactured using ultraprecision diamond turning by Spaceoptix, a specialist for high-performance optical metal components and systems for applications, amongst others, in space or astronomy. The elliptical shape is manufactured by means of a multi-axis turning machine (Fig. 3a).

When the laser beam is travelling through the mirror system, there is a power loss of 15 %. However, the resulting warming of the mirrors, due to absorption, is negligible and the residual laser energy sufficient for treatment of polymers. Additional coating of the

Institutes

Ernst Abbe University of Applied Sciences

The Ernst Abbe University of Applied Sciences (EAH Jena) offers a wide variety of study courses in eight departments covering engineering sciences, business administration and social sciences. One of eight main research fields focuses on optics and production engineering, especially on modern laser technologies. Our activities in laser material processing are the fundamental research of laser beam interactions, the development of special processing methods and the solving of industrial applications.

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Technische Universität Ilmenau

The TU Ilmenau is a research-strong university with a total of 44 bachelor's, masters and diploma programs. Characterized by traditional strengths in application-oriented science, it is one of the internationally recognised locations for interdisciplinary research and teaching. Scientists combine their expertise from engineering and natural sciences, computer science, economics and social sciences in three profile lines: functional materials and technologies, intelligent sensing and precision metrology as well as complex systems and data-intensive engineering.

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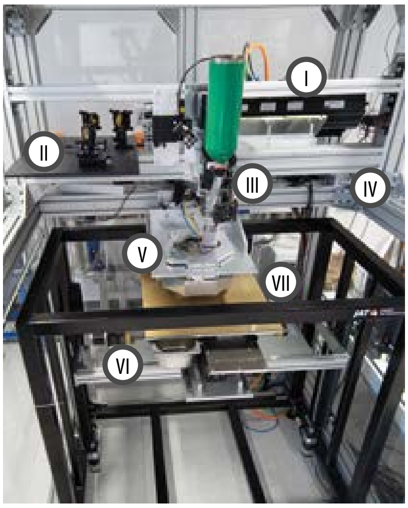
mirror surfaces, which would be very challenging and expensive for such a special geometry, is therefore not necessary. The optical design requires high accuracy of each single component, which is why the mirror system is pre-assembled and aligned by the manufacturer.

The mirror system was integrated into the experimental setup of the hybrid 3D-printing machine, consisting of seven main components (Fig. 4). A three-axis linear stage (VI) allows maximum build dimensions of 550 × 550 × 550 mm (x, y, z). A heated building platform (VII) provides sufficient adhesion between extruded polymer and the printing table. These components are decoupled from the machine rack (IV) so that extrusion and the laser process are not affected by the traverse movements. Deposition is made by a granule-processing, single-screw extruder (III), type ExOn10 from Dohle. It is equipped with a 3 mm nozzle and enables a mass output of up to 6.5 kg/h. A Synrad 48-2(S) laser system (I) with P_{Laser} = 25 W is integrated for laser beam heat treatment. The beam travels through a beam shaping unit (II) a quarter-wave mirror as well as several deflection mirrors to form circularly-polarized laser radiation. Tracking of the laser beam heat treatment is made possible by the deflection system (V). The control unit of the rotation mirror initializes the mirrors' position by means of a Hall sensor. Subsequently, it receives an analog voltage signal corresponding to the machine feed vector and calculates the angle of rotation to guide the reflected laser beam along the printing path. In addition to this setup, an infrared camera (Optris PI640) is used to monitor thermal processes.



I laser
II beam shaping unit
III single-screw extruder
IV machine rack
V laser beam deflection system
VI three-axis linear stage
VII heated building platform

Fig. 4 Experimental setup of the hybrid 3D-printing machine

System characterization

Once the setup and alignment are done, the functionality of the laser beam deflection system had to be proven. The maximum available beam deflection zone on the build platform, which covers approximately 75 % of the nozzle's circumference, can be mapped with the aid of a pilot laser (Fig. 5, left).

The response time of the laser system does not allow for active control of the laser power during the hybrid printing-process. As an alternative the beam motion can be overlaid by an oscillation. This allows dynamic tempering and enables the homogenization of the irradiation. The simultaneous heat treatment of underlying and adjacent strands also becomes possible.

The temperature field is governed by an oscillation within an angular range, described by a userdefined amplitude ($\hat{u}$) and superimposed with the vector of the machine's feed rate (V_{vf}). While V_{vf} is constant, the selected value of $\hat{u}$ has significant impact on the resulting temperature field due to a defined strand geometry (Fig. 5). The greater the amplitude, the more irregular the temperature distribution within the temperature field. In addition, temperature peaks can be seen in the inflection points. A relatively homogenous temperature distribution is found at an oscillation range of 20° ($\hat{u}$ = 10°), cf. Fig. 5c.

Based on the investigations, the overall functionality of the laser beam deflection system was proven, and the entire setup is fully characterized for further experiments.

Hybrid process with laser beam deflection system

The purpose of this examination is a reduction of process-characteristic voids. An increase in lateral strand bonding in particular, and consequently improved component properties are expected by concentrating the laser beam into the relevant area.

The material heating (ΔT) for the respective underlying strand (spot A) and adjacent strand (spot B) is detected (Fig. 6a) to determine the process window.

The process windows for PMMA and SAN can be defined by varying the laser power (P) and rotation mirror amplitudes ($\hat{u}$ = 10°, 20°, 30°). The limiting condition here is the decomposition behavior of the plastics, which manifests itself in the form of smoke formation. The results show that a lower rotation

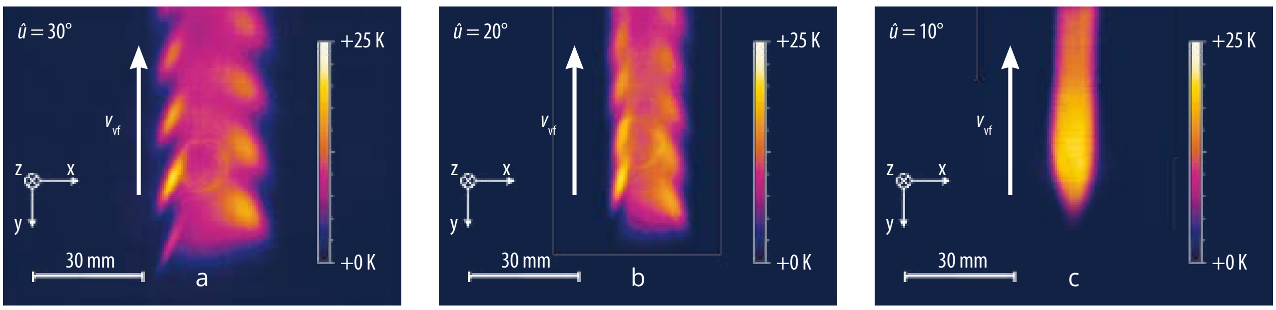


Fig. 5 Display of the dynamic tempering range at different amplitudes and its superposition with the vector of the machine feed rate

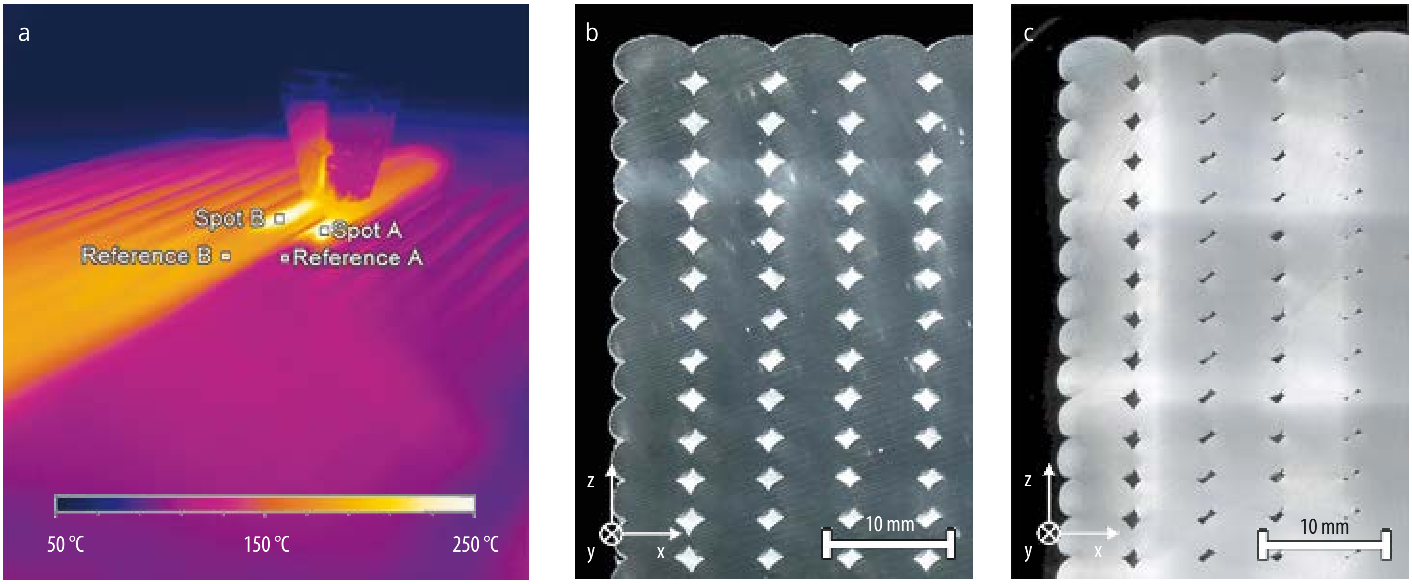


Fig. 6 Display of the measuring fields on the underlying and adjacent material strand during dynamic tempering (a), void size at LSAM (b) and reduced void size with laser-assisted LSAM (c)

mirror amplitude leads to faster heating. So $\hat{u} = 10°$ can be confirmed as the ideal parameter for the dynamic tempering of both plastics, since the temperature field has very good homogeneity and at the same time leads to better utilization of the laser power.

The new approach leads not only to a vertical but also to a lateral melting of the deposited roads. Void size is therefore significantly reduced and inner structures become more dense (Fig. 6b, c) compared to the standard LSAM process. Bending tests were carried out at PMMA and SAN based on these geometries.

Results

Test specimen fabrication and bending tests were carried out in accordance to DIN EN ISO 14125 to quantify the resulting component structure. It was found (Fig. 7) that both materials show a significant improvement in the lateral layer bond (orientation XY and XZ), which is known to be the weakest orientation. The bond quality shows an increase of up to 425 % (XY PMMA) and 762 % (XY SAN).

Overall, the laser-assisted process leads to an improvement along each examined orientation. The only deviation was found in the value of XY SAN, which is about 7 % lower in comparison. This can be attributed to fluctuations in the extrusion process and to the fact that the number and position of the production-related cavities in the test specimens are determined randomly when the bending specimens are cut to size. For this reason, the standard deviations for all results are, in principle, correspondingly large.

Compared to the injection-molded solid material, the closest approximation is achieved along the strand direction. This again confirms the ortho-

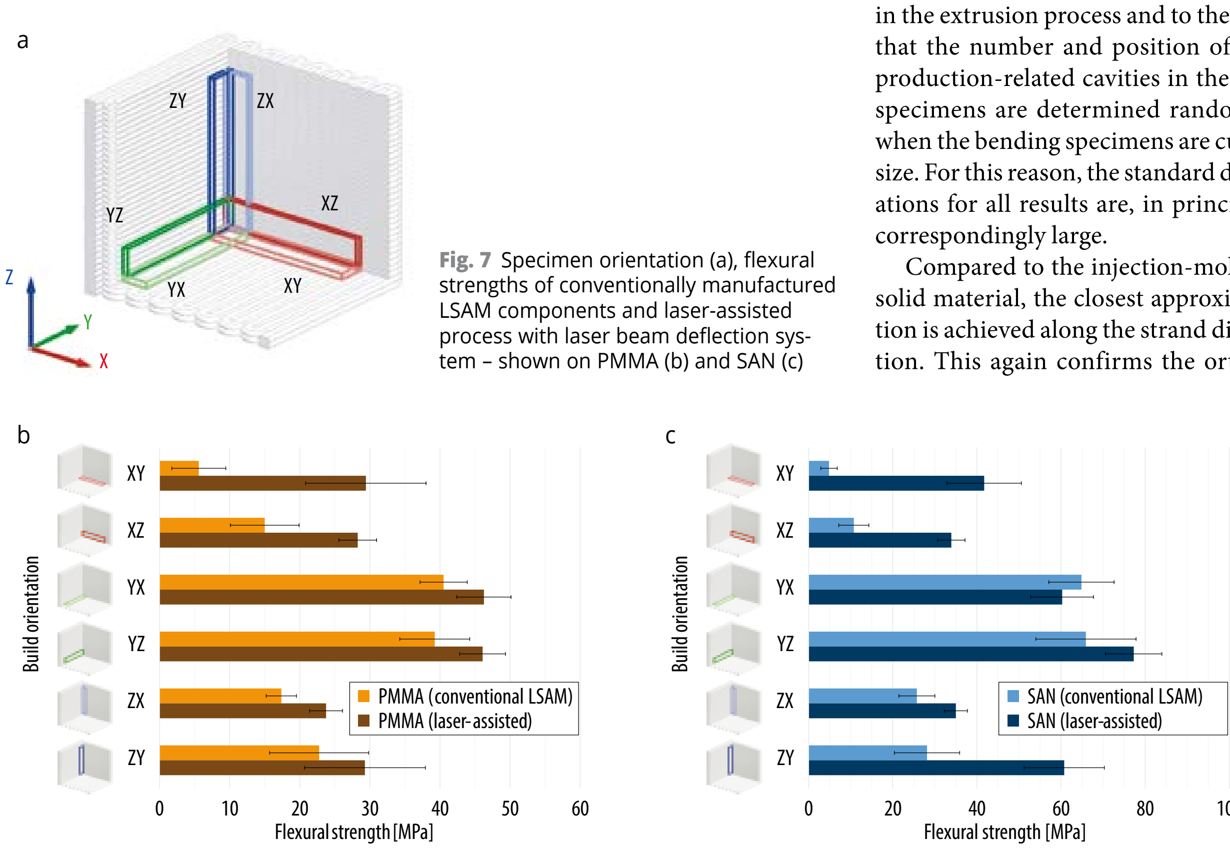


Fig. 7 Specimen orientation (a), flexural strengths of conventionally manufactured LSAM components and laser-assisted process with laser beam deflection system – shown on PMMA (b) and SAN (c)

tropic properties of LSAM parts. The maxima obtained for PMMA and SAN correspond to an increase of about 11 % compared to the conventional LSAM process. All other orientations show an average increase of 20 % for PMMA and 24 % for SAN.

Summary and outlook

The results confirm the hybrid process with incorporation of the laser beam deflection system as an effective tool to significantly improve part properties using LSAM. Lateral bonding in particular is significantly improved compared to the conventional LSAM process. The laser beam deflection system provides high flexibility with regard to part orientation and printing direction. The temperature field can be individually adjusted by controlling the laser power as well as the beam oscillation. Further investigations will focus on materials such as semicrystalline polymers as well as composites of glass, metals, and ceramics.

*

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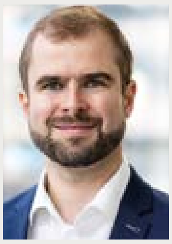

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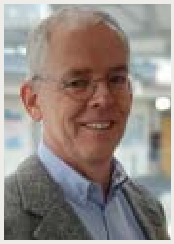

René Theska received his Dipl.-Ing. and Dr.-Ing. degrees in precision engineering from TH Ilmenau / TU Ilmenau, Germany. He then worked on tactile and optical CMM technology as the head of R&D at Hexagon Metrology in Wetzlar, Germany. In 2001 he was appointed as professor for precision engineering at TU Ilmenau. His research focus is on the design of ultraprecise devices for the measurement of length, force and torque as well as on nanofabrication machines.

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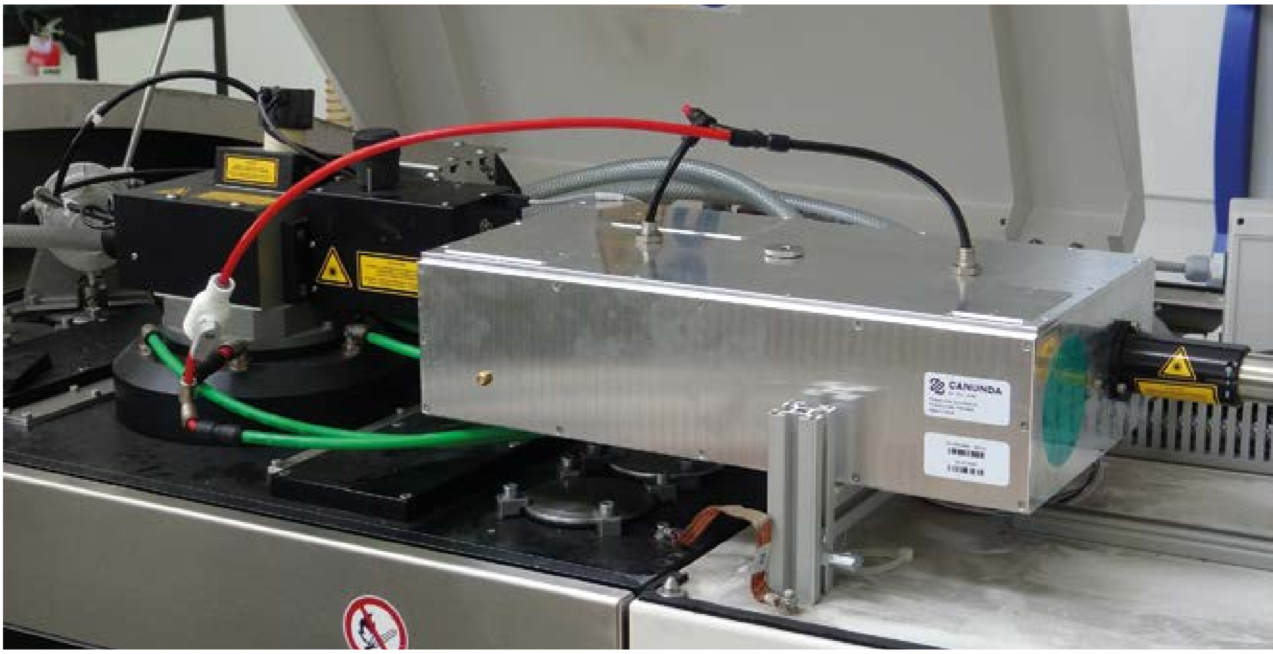
Advances in laser powder bed fusion thanks to beam shaping

Beam shaper based on multi-plane light conversion enables new forms of material processing

Julien Bayol and Gwenn Pallier



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▲ Cailabs' reconfigurable beam shaper

Cailabs have designed a reconfigurable beam shaper dedicated to the laser powder bed fusion process that is able to produce an ellipse, ring or round top-hat beam profile in the processing plane. This study highlights the potential of beam shaping to improve the quality and productivity of the additive manufacturing process. Using a machine which was not initially able to print Inconel 939, the round top-hat shape made it possible with a large scan speed process window.

Laser powder bed fusion (LPBF) is an additive manufacturing process with great potential in terms of flexibility, prototyping, and part geometry. However, it still needs to overcome certain challenges, such as increasing productivity and printing new materials. LPBF is a complex process, so a number of possible approaches can be taken to address the challenges, including inert gas management, scanning strategies, and adjusting the optical parameters of the laser beam. One method of the latter approach is spatial beam shaping.

Beam shaping optimizes the way the laser energy is deposited on the powder bed, giving improved power density, and allowing better control of the thermal gradient in the fusion zone. Although these two objectives have often been in conflict, the resulting improvement in process quality solves the first challenge of increased productivity mentioned above. Firstly, beam shaping has the potential to stabilize the process, increasing the power and scanning speed. Moreover, process quality improvement could be expressed through a reduction or elimination of the phenomenon of hot cracking. On a general level, this can result in a productivity increase by reducing the number of rejects or post-processing steps. Increasing the density parameters could eliminate the need for hot isostatic pressing (HIP), which accounts for a significant portion of the manufacturing time of a part. Similarly, more precise control of the deposited energy and thermal gradient could allow new materials to be printed, such as nickel-based superalloys, which are prone to hot cracking.

Compatible with the scanner, integrated into an LPBF machine

The Additive Manufacturing with Laser Beam Shaping (AMLABS) project, carried out by Pres-X and Cailabs, is studying the ability of beam shaping to address these challenges. Cailabs, a

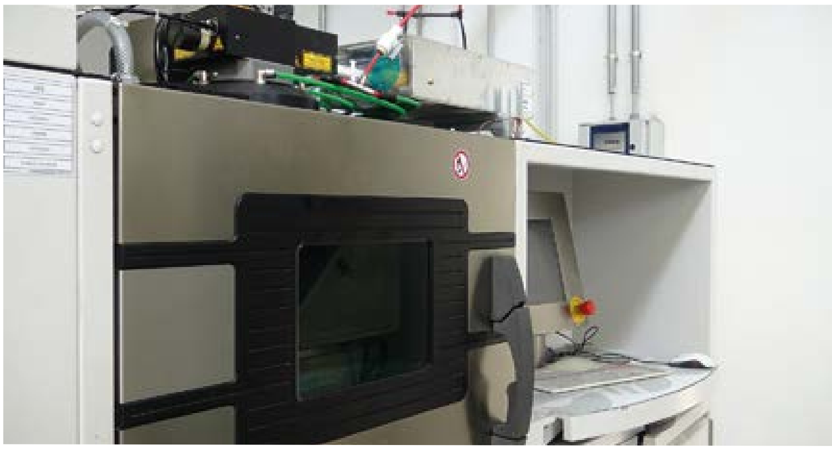

Fig. 1 The beam shaper integrated on the LPBF machine

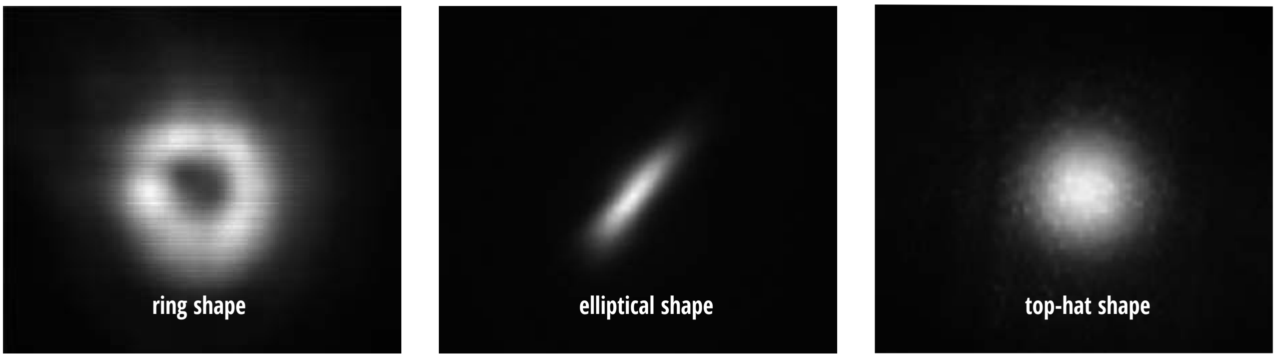

Fig. 2 Measurement of the three shapes in the processing plane of the machine

French deep-tech company, is leveraging its proprietary beam shaping technology, multi-plane light conversion (MPLC), to develop a reconfigurable beam shaper that can create three different beam profiles: an ellipse, a ring and a round top-hat. Pres-X, an Italian company specializing in additive manufacturing with a focus on post-processing, is responsible for manufacturing and characterizing the samples.

The reconfigurable beam shaper was installed on an EOS M280 machine belonging to the Beamit group, the parent company of Pres-X, to assess the performance of beam shaping. The laser input source was an IPG YLR-200-SM-EOS with a maximum power of 200 W, inserted between the collimator at the output of the laser fiber and the input of the machine's scanner. The beam shaping produced by Cailabs was compatible with the scanner and F-theta lens, so the beam could scan the powder bed. It could also be installed directly on the machine without requiring any mechanical adjustments, thereby protecting the security of the machine and its programs.

Three beam shapes, one module

The beam shaping module developed by Cailabs is based on MPLC, a technology that can shape one or more laser beams to generate any symmetric or asymmetric beam profile. It also controls the beam phase in the shaping plane, which ensures a greater depth of field compared to other beam shaping technologies. The beam is shaped by a succession of phase planes with sufficient propagation distance between each plane. MPLC is implemented using reflective optical components (mirrors) which optimize power management and reduce focus shift by cooling the optics from the back.

Three beam shapes were created with the following dimensions in the F-theta plane:

- ring shape: average diameter 150 µm, 70 µm FWHM (full width at half maximum)
- elliptical shape: 90 µm x 280 µm @1/e²
- round top-hat: diameter 90 µm @1/e²

A single mechanical casing was manufactured with interchangeable beam shaping optical components inside to enable switching from one shape to another. This 'multi-static' approach provides versatility while retaining the benefits of conventional static beam shaping – better shape quality and stability. Changing from one shape to another required re-aligning the module's optical components. The transmission over the whole optical chain, including the beam shaping components, was higher than 90% for each configuration.

Evaluating the process window and performance with the three beam shapes

Circular rods were printed on separate areas of the build plate using different printing parameters to assess the impact of beam shaping on the process. At this stage of the project, consolidated results on ring and round top-hat shapes allowed initial conclusions to be drawn

Company

Cailabs

The company was founded in 2013 and is a French deep-tech enterprise that designs, manufactures and sells innovative photonics products for telecommunications and industrial lasers. A world leader in complex light shaping, its technology is currently covered by 19 patents. Its innovative components are used in various fields, from aeronautical wiring to factory local area networks, including laser manufacturing. They have contributed to several world records (in particular, the fiber optic throughput record held by the Japanese operator KDDI).

www.cailabs.com

on the contribution of beam shaping to the process.

During testing, a preliminary but essential point needed to be validated: that the power density of the shaped beam would be sufficient to initiate the fusion process. Changing the size of the shaped beam at limited power (200 W) affected the power density on the powder bed. The first step was to print a part to confirm that the power was sufficient to make the powder fuse.

Parameter optimization testing was then performed on Inconel 939 to establish the process window. The parameters used were as follows:

- laser power: 195 W
- hatch distance: 0.1 mm
- layer thickness: 0.04 mm
- scanning speed: 550 – 920 mm/s

Finally, more extensive testing was conducted using the established optimal parameters, including the micrographic and mechanical characterization of printed samples on different areas of the build plate. The purpose of this testing was to evaluate the absolute quality of the parts produced, comparing them to reference values and validating the robustness and repeatability of the process over the entire build plate.

We cannot present a comparison with a part manufactured without beam shaping, simply because it is not possible to manufacture parts in Inconel 939 on this machine without beam shaping.

High quality Inconel 939 printing thanks to the top-hat shape

The first shape tested was the ellipse. The samples manufactured with this shape were unsatisfactory, because the power density was insufficient to fuse the powder to produce parts of acceptable quality.

The second shape tested was the ring. A single configuration at the lowest speed produced satisfactory quality samples with a measured density of over 99.9 % and no cracking. The other samples produced at a higher speed showed signs of hot cracking and significant porosity, possibly due in part to a lack of fusion (see Fig. 3). These results confirmed the important contribution of beam shaping to the process. Beam shaping made it possible to produce high quality parts using Inconel 939.

Fig. 3 Micrographic evaluation of samples made with the ring shape at different scan speeds; (left) ring shape – scan speed: 550 mm/s – ×50, (right) ring shape – scan speed: 690 mm/s – ×200

Tests were then conducted on different areas of the build plate at the lowest speed. No cracks or porosity were identified on any of the samples, and the micrographic and mechanical properties were homogeneous across the entire build plate, demonstrating the robustness of the beam shaping across the entire field of the F-theta lens. During micrographic analysis it was observed that the size of the melted zone was smaller on pieces produced using beam shaping (500 µm diameter for the ring shape) than on those without (800 µm with a Gaussian beam, produced using another machine).

This phenomenon can be correlated with the size of the beam in the working plane, the top-hat shape enabling the use of a smaller beam diameter compared to a Gaussian one. Indeed, reducing the size of a Gaussian beam generates a high energy density peak at the center of the beam, potentially damaging the material through several layers, which is not the case with the top-hat shape thanks to a homogeneous plateau intensity.

These results show that beam shaping removed the first barrier regarding the project's objectives, since it had not previously been possible to print parts in Inconel 939 with this specific type of machine due to its limited power. It should be noted that it is possible to manufacture parts using Inconel 939 on other more powerful machines, so the contribution of beam shaping is demonstrated here with all parameters being equal. Further studies on the impact of beam shaping on a newer machine will be conducted in the future.

Concerning the productivity objective, still using Inconel 939, the printing speed was about 40 % lower for the machine with beam shaping compared to a conventional beam (using 2× higher laser power). However, the high quality of the parts produced with beam shaping and the absence of cracks could reduce the post-processing time and therefore the overall manufacturing lead time, because the hot isostatic pressing (HIP) step could potentially be eliminated.

The final shape tested was the top-hat. The results with this shape are even

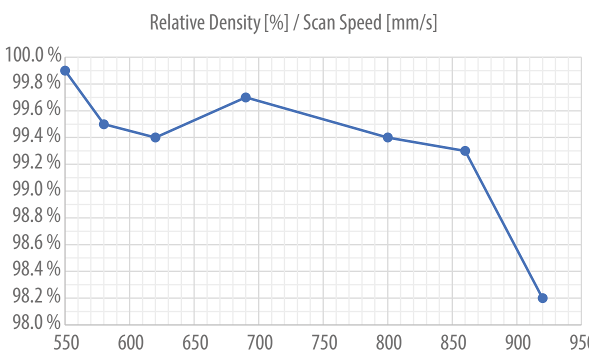

Fig. 4 Using the ring shape, the density is acceptable only for the lower scan speed

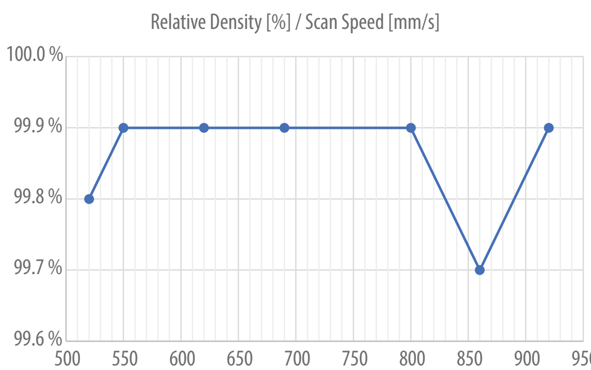

Fig. 5 Using the top-hat shape, the density remains stable using different scan speed

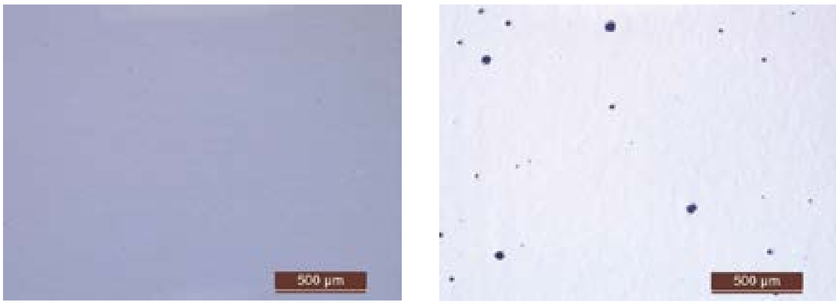

Fig. 6 Micrographic evaluation of samples made with the top-hat shape at different scan speeds; (left) top-hat shape – scan speed: 800 mm/s – ×50; (right) top-hat shape – scan speed: 860 mm/s – ×50

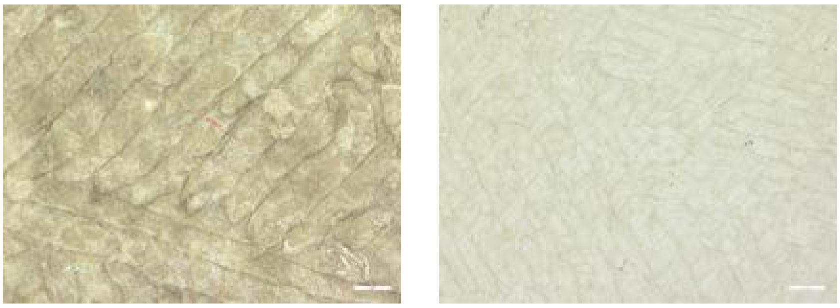

Fig. 7 Micrographic evaluations of samples made with best configurations of both ring and top-hat shape made; (left) ring shape – dentrite width: 500 µm, (right) top-hat shape – dentrite width: 250 µm

more encouraging than with a ring. As the density of the samples is much less sensitive to an increase in scan speed, the latter could be increased by a factor of almost two, and compensating for the lower printing speed mentioned above. Some circular porosities have been found at 860 mm/s scan speed, but no lack of fusion, keeping the density of the samples above an acceptable level.

Samples were then printed on different sections of the build plate at the highest speed. Here the process was also not affected by the position of the sample on the build plate, and no porosity or cracks were observed. Analysis identified a finer microstructure than with the ring shape, which may be one of the reasons for the enhanced mechanical properties compared to the ring shape [1].

It would appear, therefore, that a top-hat profile performs better than a ring profile: it has a wider process window in terms of scan speed, and superior mechanical and micrographic properties, while keeping process robustness across the entire build plate.

Conclusion

MPLC technology has made it possible to design a reconfigurable module which, by interchanging optical components, can generate an ellipse, a ring and a top-hat beam shape in the processing plane. The latter two produced parts with homogeneous properties across the entire working plane. The module can be integrated into the optical chain of the machine, and into the machine itself.

This study highlights the potential of beam shaping in powder bed fusion additive manufacturing. We demonstrated that the MPLC beam shaper expanded the process window of a specific machine. Using the ring and top-hat beam profiles, the EOS M280 was able to print Inconel 939 parts that met the density and no-cracking requirements, which had not previously been possible. The quality of the parts produced could also result in increased productivity due to the reduction in post-processing times.

The potential brought by this beam shaper can be used in two different ways. It can be installed on new machines to print new materials and expand the catalogue with new configurations that were previously not possible with LPBF. It can also be used on an ad hoc basis to upgrade machines that are already in operation. Retrofitting existing machines would allow them to process off-catalogue, state-of-the-art, printable materials (exactly what has been achieved with this project). This approach is particularly interesting from a financial perspective, as it is much less costly to install a beam shaper than to purchase a new machine.

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[1] *X.-H. Yang, C.-M. Jiang, J.-R. Ho, P.-C. Tung, and C.-K. Lin:* Effects of Laser Spot Size on the Mechanical Properties of AISI 420 Stainless Steel Fabricated by Selective Laser Melting. Materials, **14** (2021) 16, 4593. doi:10.3390/ma14164593.

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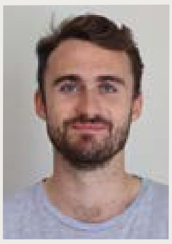

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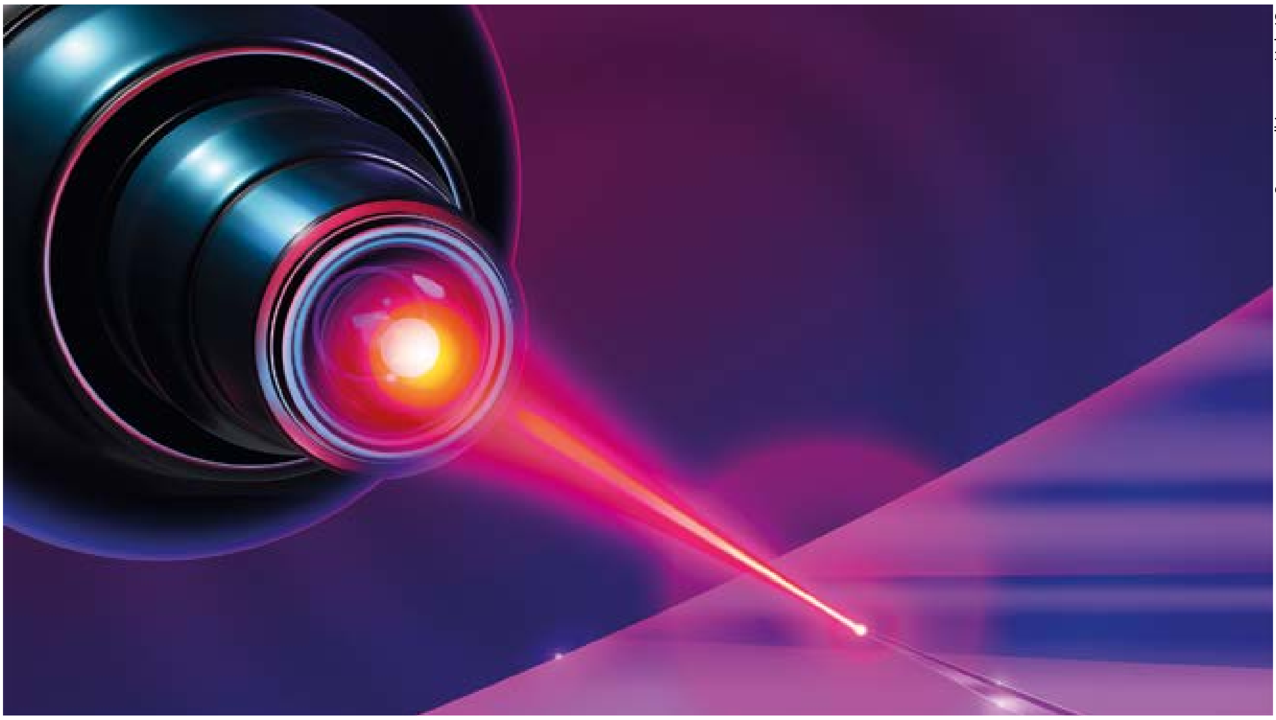
3D beam shaping methods for ultrashort-pulsed laser material processing

Improving process speed and enabling new industrial laser applications by 3D beam shaping

Alexander Brodsky and Natan Kaplan



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Ultrashort-pulse (USP) lasers enable microlevel manipulation of material surfaces and work on the bulk of transparent materials with almost no thermal effects. One major bottleneck that is limiting the processing speed with USP lasers is the effective spreading of laser energy in the processed material. Diffractive optical elements (DOE) are a leading method of solving this bottleneck. In this article, we review the concept of 3D diffractive light shaping for USP lasers and show its usefulness in various industrial USP laser applications.

With the increasing availability of USP laser power, interest in USP laser applications is at a fever pitch, and USP processes are becoming the standard industrial practice in certain fields of application. Based on feedback that Holo/Or received from customers, we can say that the following USP applications are of interest to many laser machine integrators:

- Laser-induced periodic surface structuring (LIPSS) to make surfaces hydrophobic or hydrophilic, or to change tribological properties.
- Glass cutting, drilling, welding, and chamfering, as well as laser-induced chemical etching
- Semiconductors (including solar panels, and the display industry) and other wafer level applications including scribing, annealing, and wave guide creation for AR, VR solutions
- micromechanical engineering by laser printing or etching
- microfluidic channels in lab-on-a-chip applications
- two-photon polymerization

Another indication for the level of interest in USP for industrial applications is the large number of European joint projects that are using USP lasers. Such projects in recent years have covered diverse applications such as laser surface texturing of large surfaces, structured surfaces for tools and molds, and laser microdrilling.

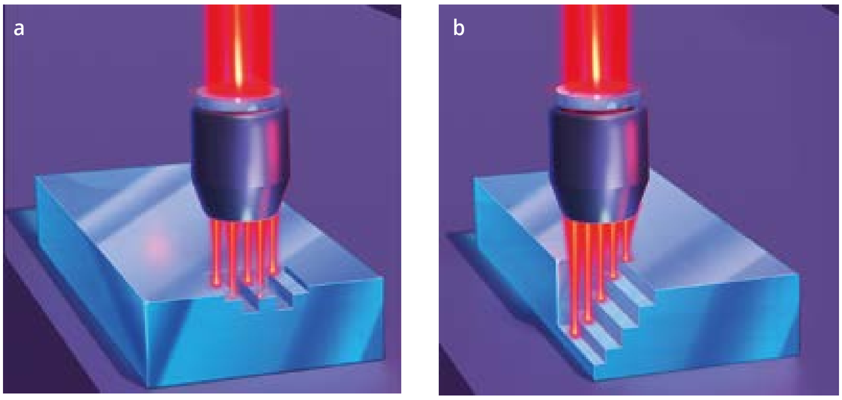


Fig. 1 Parallel laser processing with a 3D beam splitter: (a) wafer surface with two levels (b) stair-like surface.

The USP challenge

Despite the great strides already made in USP laser application and the increasing power of the industry-grade USP lasers now available, there are still many applications where USP processing is still too slow. This is often not due to power limits, but rather to limits imposed by other constraints such as the need to scan in several axes, including depth. This is especially true when working with complex 3D geometries such as the surface of real, curved parts, or when working inside the bulk of transparent materials.

One of the leading methods of overcoming some of these constraints is beam shaping. Creating custom distributions in a certain work plane is a well-established method of optimizing laser processes and increasing throughput. Another common type of shaping is focal shaping, where the energy is re-distributed along the focal axis, creating multiple foci or elongated focal regions in a transparent material.

However, for complex geometries, 2D shaping at a target plane or shaping only along the focal axis is not enough. Complete freedom of shaping in three dimensions is required to deliver power at the desired points.

In response to this need, and drawing on Holo/Or's knowledge of beam shaping, as well as work done by others in the industry, we wish to present the concept of 3D beam shaping.

What is 3D beam shaping?

3D beam shaping relies on diffractive optical elements (DOEs), a well-known and effective method of beam shaping. The basic idea behind DOEs is arbitrary control of the intensity by using the diffraction phenomena. DOEs are phase masks that can create any arbitrary phase profile, which is then translated into an intensity profile in the far field. DOEs are used for parallel processing by splitting a single beam into an array of beams, for shaping of the laser beam to a tailored shape (typically with flat-top intensity), or some combination of the two. In addition to 2D shaping in the x-y focal plane, there is also axial shaping, i.e. focal shaping.

One example of this type of shaping is multifocal lenses that focus an incident beam into several discrete foci along the optical path. Another example are Bessel-like beams (such as those generated by an axicon) that have a continuous shaping profile along the optical axis. Axial shaping is relevant for transparent materials (for the specific wavelength used) and is mostly used to induce nonlinear effects in the material bulk.

The simplest way to describe 3D beam shaping is a combination of spatial and axial diffractive beam splitters that create an array of focal points in 3D space, rather than only at a target plane.

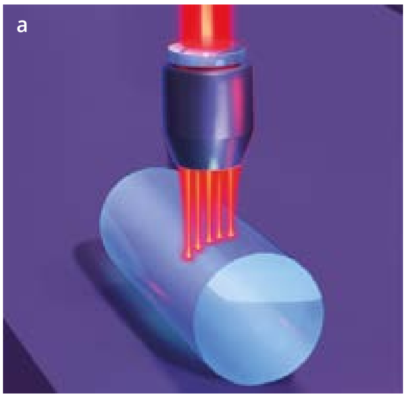
A simple example of that is splitting to two orders in the x plane and two orders in the z plane (along the optical axis). The resulting effect is four orders in the x-z plane, i.e. two focal planes where in each plane there are two spots. 3D shaping extrapolates this concept to fully free orders positions in space/volume, with pre-determined, controlled separations.

Since DOEs are thin and flat elements with a diffractive pattern etched directly into fused silica, they have little bulk where temporal dispersion can take place, and are thus a perfect fit for UPS high power lasers. This is further enhanced by reflective mode DOEs for cases where absolutely no dispersion is permissible.

3D beam shaping is relatively new to the industry. Here we show some surface modification ideas for how a 3D splitting technique can improve existing applications that currently use a single beam, or to inspire novel optical applications.

Wafer-level parallel processing at different heights

Our first example implements 3D shaping for scribing applications by parallel scanning multiple channels with high NA optics at individual heights, as shown in Fig. 1a for five channels run on



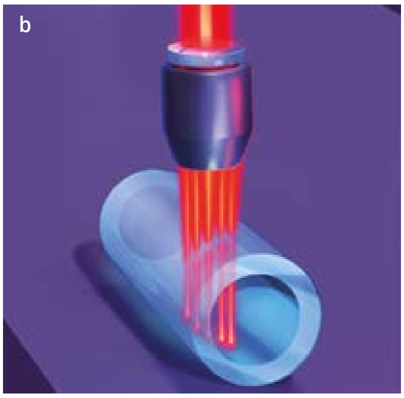


Fig. 2 (a) structuring the outside of a cylindrical surface with a 3D array of beams to correct for the curvature (b) structuring the inside surface of a transparent tube or cuvette by a 3D beam shaping element with freeform correction for a curved surface.

a wafer with two discrete height levels. Another example is shown in Fig. 1 that operates on a stair-like surface.

Such multiplane scribing can simultaneously pattern various height levels in the wafer, or even create staircase-like structures on smooth edges in a single laser pass, improving process throughput for laser wafer processes. Applications can be GaN LED substrate texturing (to enhance adhesion compared to a smooth sapphire pyramid surface while retaining high transmission), laser ablation of copper to create contacts on top of waveguides, and many others.

Laser surface structuring (LIPSS)

In many LIPSS applications, the work surface is a plane, but in other cases the surfaces have more complex geometries such as convex cylinders for glass tubes/cuvettes, metal screws, cylinder liners, and rolls for roll-to-roll manufacturing. 3D optimization can be applied individually per order or as a full-field, single continuous function correction. Fig. 2 shows possible use scenarios of 3D shaping on cylindrical geometries.

Such 3D shaping to correct for surface curvature can be achieved by a single DOE that both splits the beam and corrects for the curvature, without any need for complex, multielement cylindrical lens systems that are currently employed for such curved surface corrections.

Advanced laser glass cutting, including beveling

A growing fraction of laser glass cutting is done by utilizing ultrashort pulses at IR and green wavelengths to generate non-linear filamentation effects in the glass, resulting in high quality edges with micron scale waviness. These cutting methods often employ Bessel-like beams to create an elongated focus effect, as there is a need for a very tight focus over the entire thickness of the glass to be cut. These are usually created by Axicons (including diffractive axicons), or by tailored axial top hat shaping, such as Deepcleave from Holo/Or, which has certain process benefits.

Although current cutting solutions are capable of cutting flat surfaces in a straight line, i.e. for the main cut, often a chamfer is desired at the edge to protect from cuts when handling the glass and to improve the mechanical durability of the glass. These chamfers currently require a separate, additional chamfering step, such as grinding or laser process, in addition to the main laser beam cutting laser step.

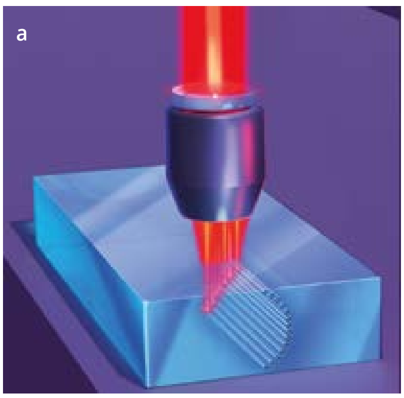
There is interest in the laser industry in a laser cutting process that can combine the main cut and chamfering step. This can be achieved by means of 3D beam shaping to generate multiple spots in the bulk in a pre-determined arrangement. An example of such a shaper has been developed and tested by a team from Trumpf. Other shaping paths such as trapeze bevels (rather than rounded edges) are possible, and can be designed by Holo/Or.

A similar method could be employed to cut-out microgrooves or channels in transparent materials without the need to ablate the material. This has the potential of greatly increasing the throughput of microgroove texturing for applications such as microfluidics, LED substrate production, and many others.

In Fig. 3a we show an example of C-shape chamfering and in Fig. 3b we show a way to make rectangular microgrooves with steep edges using a similar technique in the z-x plane.

Volume modification by 3D ordered or random arrays

Transparent materials can be modified by focused USP pulses through the mechanism of laser induced damage. These modifications include refractive index changes, increased scattering and changed mechanical properties. Even cavities in the bulk or enclosed tube-



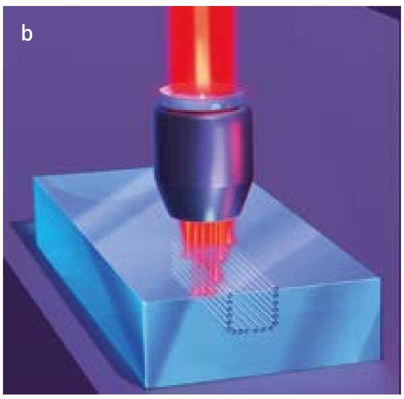


Fig. 3 (a) glass curved cutting and chamfering with a C-shape 3D beam splitter (b) selective etching of channels with steep edges within glass or other transparent medium.

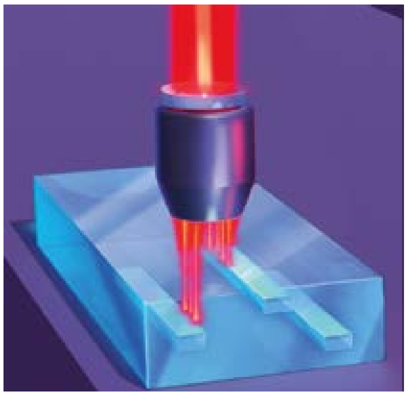


Fig. 4 Simultaneously writing multiple microchannels in glass by a combination of 3D beam splitter and scanning.

like channels can be created by filamentation, non-linear effects or methods such as laser enhanced chemical etching. Such modifications are currently typically done spot by spot in the bulk, or created only on a single plane in the bulk by means of scanning.

A pre-determined pattern of modified areas can be generated without any need for scanning or movement by utilizing 3D beam shaping. Such patterns can include ordered or random arrays of cavities in the bulk, useful for applications in microfluidics and other fields.

A typical application of bulk modifications is in lab-on-a-chip microfluidic production. It is possible to simultaneously make several channels in separate x-y-z positions by applying 3D shaping. Such an idea is schematically presented in Fig. 4, with channels positioned at different depths and spatial positions.

Summary

The ultrashort-pulse laser field is continuously growing and provides new opportunities for applications. Many of these are currently in the development stage and a few, such as laser glass cutting, have already hit the markets. Costs and productivity are the main limiting factors to introducing this technology on an industrial scale. In this article, we showed some novel ideas for the implementation of 3D diffractive beam shapers in existing USP laser applications to enable attractive, cost effective solutions. We believe in the great potential of USP lasers combined with 3D shaping by DOEs to enable products with unique characteristics of efficiency, durability, and economy of resources and energy.

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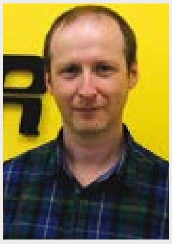
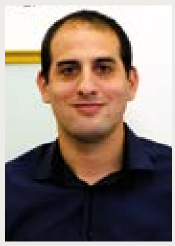
Authors



Alexander Brodsky is Holo/Or's R&D optical systems design engineer. Specializing in laser optics solutions involving diffractive optical elements, Alexander is Holo/Or's lead designer when it comes to combined diffractive-refractive system design. He has eight years of experience in micro-optics development and has authored several peer-reviewed papers about beam shaping methods for M^2 transformation. Alexander has a bachelor of science degree in applied physics.



Natan Kaplan is Holo/Or's R&D manager. A graduate cum laude of the Adi Lautman program for excellent students at Tel Aviv University (physics BSc), Natan went on to specialize in subwavelength structures for antireflective purposes in the mid-IR, where he finished his MSc under the supervision of Avraham Katzir. He has about ten years of experience in micro-optics development and co-authored two articles on laser material processing and several white papers on diffractive optics. He has managed projects within the Horizon 2020 framework (Ultrasurface), as well as other projects (ALTIA, Israeli MAGNET program, Eurostars MultiLas cooperation).

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Heat conduction joining with the multispot focusing lens

Joining plastics and metal

Cornelia Halbhuber

Fig. 1 Multispot welding head during operation

Source all images: Sill Optics

Despite the rapid development of modern lasers, the Gaussian intensity distribution often leads to problems, especially in laser material processing. When welding wide weld seams, a top-hat profile would often make much more sense in order to heat the weld seam as homogeneously as possible. In narrow curves, the different feed rates on the inside and outside of a wide weld seam result in further inhomogeneity. For this reason, a special optical system was developed that delivers homogeneous intensity distribution – both in straight lines and in narrow curves. The intensity distribution of a wide top-hat profile can be changed locally and temporally by nine parallel beams. The welding head is installed on a robotic arm that travels along the weld seam and temperature homogeneity of >90 % within the spot can be achieved.

Based on Einstein's principle of stimulated emission, Charles Hard Townes succeeded in 1958 in developing the maser which emitted microwaves, the forerunner of today's laser. Just two years later, Theodore Maiman produced the first laser for which no applications were known at that time. In 1962, the semiconductor laser was finally invented and found its way into the mass market in the following years because of its small size. The variety of applications for the laser now became more and more diverse, which helped its rapid development [1].

Industry today is absolutely dependent on modern lasers. Extremely powerful, ultrashort-pulsed (USP) lasers with pulse durations of only a few femtoseconds are used in medical and measurement technology as well as in manufacturing technology and many other industries. However, all lasers have one problem in common, especially with joining techniques such as laser welding: the Gaussian intensity distribution.

A top-hat profile would be significantly better here so that the temperature distribution within the seam would be as constant as possible [2]. In order to solve this problem, diffractive optical elements (DOEs) are often installed in the beam path to shape the spot. They provide an adequate intensity distribution in a straight line, but the problem arises again in narrow curves.

A radius problem

Especially with wide weld seams, there is a large difference in the feed rate on the outside (v_1) and inside (v_2) of a curve with a narrow radius. (Fig. 2). Since the residence time is significantly longer inside than outside, there is an increased energy input at this point which leads to degeneration of the thermoplastic within the weld seam. Conversely, the energy input is too low on the outside so that the material is not completely melted. As a result, the weld seam becomes unstable on both the inside and the outside and can withstand stress only in the center. For materials that are easy to join, the weld seam is made as narrow as possible so the difference in speed is minimum and the stable core area makes up the maximum proportion of the width.

A large joining area is indispensable for stability when joining very different materials such as plastics and metals. Homogeneous temperature distribution is therefore enormously important for the resulting large seam width and the necessary large spot diameter, even in curves.

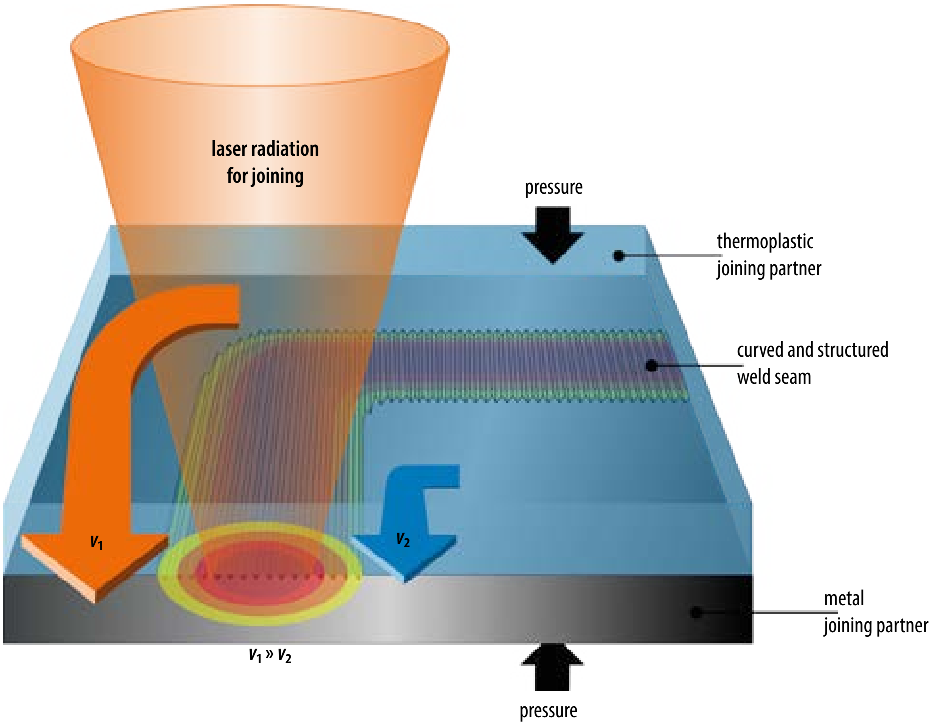

Fig. 2 Heat conduction joining in a curve

Joins with wide weld seams

Joining plastics and metals

Metal body parts often have to be joined with plastic interior components in the automotive industry. The properties of the two materials are extremely different, which makes welding difficult. Since most plastics burn at temperatures far below the melting point of metals, uniform melting of the two elements is nearly impossible. The technique of heat conduction joining is an option in such cases whereby the metal part is structured by another laser process beforehand. The thermoplastic item and the metal part are then pressed and the metal is warmed up by the joining laser. Heat conduction leads to a rising temperature of the melting plastic. The liquid thermoplastic part is now able to fill the structure of the metal part, which provides the connection. It is possible to adjust the temperature of the thermoplastic part by changing the pressure between the two elements being joined (Fig. 2) [3].

Temperature homogeneity in a curve

A special welding device was developed to enable a homogeneous temperature even at different feed rates within a narrow curve. The device consists of a three-by-three matrix of small lenses. Every individual focusing lens receives its own input beam from an optical fiber and its own laser diode. The laser power from the different optical fibers can be adjusted individually so that the power at the nine different focal points can be changed. There are now nine spots arranged in a grid in the focal plane (Fig. 3, left).

However, if a slight lateral offset is used, the Gaussian profiles of the individual spots become wider and overlap at the edges. This results in a square, extended top-hat profile which is quite

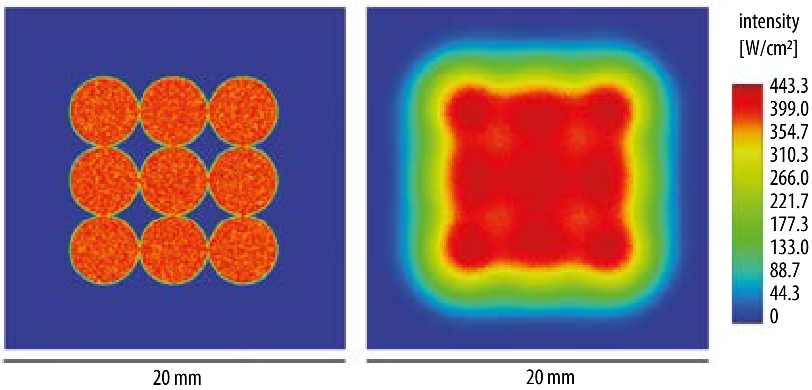

Fig. 3 Spot shape at the focal plane (left) and at the working plane (right)

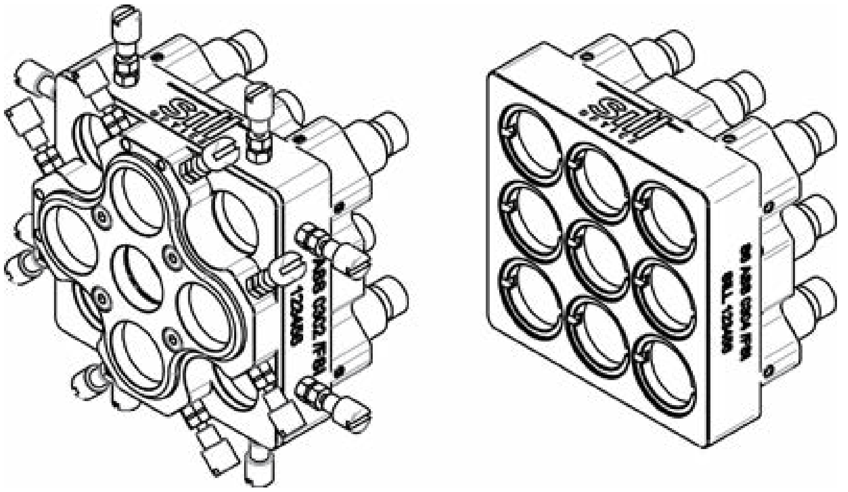

Fig. 4 Multispot lens with (left) and without (right) adjustable x-y position

homogeneous in itself (Fig. 3, right). Straight welds are no more a problem with this device even if all lenses receive the same input power due to the resulting wide top-hat profile. In a curve, the track speed of the inner rays is smaller than of the outer rays. The energy difference due to the speed difference can therefore be compensated by the adjusted power control of the individual channels [4].

Setup of the welding head

A diode laser with nine separately controllable laser diodes enables the intensity of the top-hat profile to be adjusted in the working plane. Optical fibers connect the laser and the lenses. The laser beams are focused by the small, adjacent lenses. An exchangeable protective window in front of the lenses keeps dust and dirt particles away. This means there is no risk of lens damage due to dust particles in the laser beam path.

There are nine spots arranged in a grid at the focal plane. If the working plane is moved backwards about 100 mm along the z-axis, the laser beams overlap to form a uniform top-hat profile. The entire equipment is installed on a robotic arm that traverses the weld seam. Therefore no scanner is necessary, which highly simplifies the optics. A clean top-hat profile only needs to be achieved at one point in the working plane rather than at a flat scan field because the input beams are not deviated. There is also no need to worry about any scanner mirrors with external back reflections. Lenses to collimate the input beams are also not necessary. The fiber end is focused directly through the individual lenses. Because of the offset between the working and the focal plane, diffraction-limited imaging is not necessary since small focal points are not important here.

Special features of the optics

Thermal focus shift

Special attention was paid during development to thermal focus shift caused by the individual lens elements in an objective being heated by high laser power. This results in material expansion of the lenses proportional to the glass thickness at the corresponding position. In the case of a biconvex lens for example, the material thickness at the center is significantly greater than at the edge, which reduces the lens radius with increasing temperature. The focal plane of the entire lens shifts and the imaging quality decreases.

In addition, the refractive index of many simple optical glasses is strongly dependent on temperature, which further intensifies the thermal focus shift. The higher the input power, the more the individual lens elements are heated and the more intensive is the effect of the thermal focus shift.

If the nine different lenses in the setup described are exposed to different input powers, the thermal focus shift will also have a different effect on the lenses. So the individual focus positions shift and are no longer on a flat working plane. Therefore it is very important to minimize the thermal focus shift of all lenses in order to adapt their thermal behavior as much as possible.

Fused silica is a highly transmissive material whose refractive index has only a small temperature dependence. The material is ideal for avoiding thermal focus shift and was chosen for the lenses of the welding head. The lenses were also equipped with a high-quality coating that ensures very low loss of light at transfer from air into fused silica and from fused silica into air.

This reduces the reflection loss of about 4 % per area to values below 0.5 % per area at the corresponding wavelength. More importantly, the absorption in the coating is in the single-digit ppm range. The lower the reflected and absorbed amount of light, the lower the heating of the lenses.

A cooled lens tube additionally ensures a homogeneous climate at the lenses and further reduces thermal focus shifting.

It is also important to avoid any vignetting at the lens mount. Laser radiation is particularly well absorbed by the metal mount which would heat up the mount and thus the included lenses. This can be avoided by using lenses whose free diameter is larger than the beam diameter at the lens. The proportion of the light reflected at the lens surfaces is minimized by the coating.

Due to this design, a minimum amount of the laser power remains in the lenses and keeps the lens temperature at a very low level. The cooled lens housing reduces the lens temperature again. The hardly noticeable radius changes and a temperature stable refractive index of the material result in a minimum thermal focus shift that affects neither the imaging quality nor the quality of the weld.

Internal and external back reflections

A ghost image is the back reflection from an optical surface that is focused by other lenses in front or inside the lens. These back reflections should be avoided in optical design as they can cause heating and thermal focus shift or, in the worst case, damage.

A ghost analysis was therefore performed on the multispot lens where the positions of all ghost images were checked and shifted to non-critical areas.

Special features of the mechanics

The quite small individual lenses that have to be mounted in a small space to create a homogeneous top-hat profile in the working plane require complex mechanics. The diameter of the lenses is just 13 mm. To compensate for manufacturing tolerances, the x-y position of each focusing lens can be adjusted individually by moving it across the optical axis and fixing it with a set screw. The lengths of the mounts differ from each other in order to be able to reach each setting screw (Fig. 4, left).

Although very good imaging quality can be achieved, the adjustment and manufacturing costs were very high in this flexible design. Therefore a successor model was designed in which all lenses are fixed (Fig. 4, right).

The imaging quality is still acceptable and the goal of >90 % homogeneity in the top-hat profile was achieved. The successor model proves to be more suitable for industrial use due to the significantly lower adjustment work.

Furthermore, the lens has to be stable against vibration because the mount is on a moving robot arm. A vibration test has shown that the imaging quality is not visibly altered by vibration if the mechanics are simple and robustly constructed.

Test of the functionality

A series of test runs was made to verify the functionality of the welding head and the resulting weld seams were examined. Firstly the front and back of a servo oil reservoir were welded as an example of joints between plastics. Secondly the interior fittings and the body of a car door were joined as an example of connections of plastic and metal. The images taken with a thermal imaging camera show the temperature distribution within the weld where curves with narrow radii are of special interest. The following figure shows an image taken by the thermal imaging camera with an optimized energy input at a curve radius of 10 mm (Fig. 5, left).

Here the weld seam is heated uniformly on both the inside and the outside. The temperature deviation within the spot is below the 10 % mark. A cross-section of this was made (Fig. 5, right) to check the quality of the weld seam by heat conduction joining.

The upper material is the transparent part while the lower material absorbs the laser radiation. No air-filled cavities or other effects are visible in the area of the weld marked in green, indicating a high weld quality [4].

Finally, a crushing test shows the high stress resistance of the weld. A shear tensile strength of >25 MPa was achieved for joints of plastic with plastic. A pleasing shear tensile strength of >15 MPa was achieved for welds of plastic to metal.

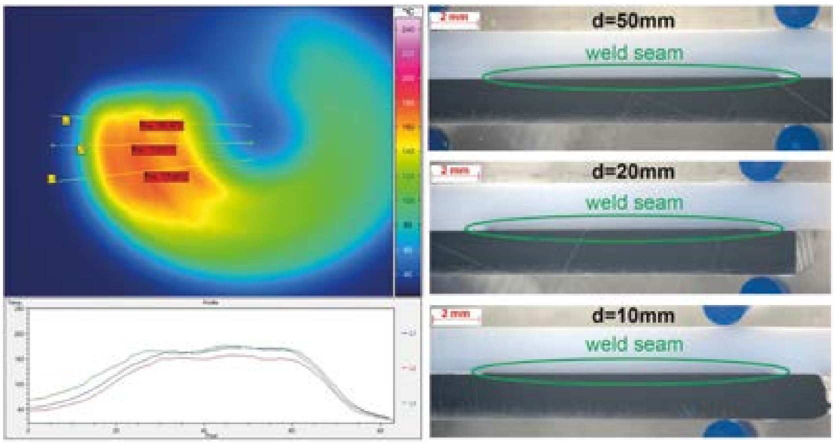

Fig. 5 Inspection of the weld seam with a thermal camera and the cross-section [4]

Conclusion

There is a need to be able to change beam characteristics during a welding process, so research has been done at many locations. The nLight company has developed its 'corona' fiber laser, which can change the beam characteristics during the process to change the spot shape [5]. However, the laser can only switch between a few different beam characteristics, which is certainly sufficient for many applications, whereas the welding device described in this article is continuously tunable. The wide top-hat profile, the high temperature homogeneity within the weld, the good imaging quality and the adjustability of the intensity within the spot make the welding head extremely interesting for difficult laser joining tasks. Wide weld seams in heat conduction joining and tight curve radii are now no longer a challenge. Highly transmissive glasses and lens coatings ensure a stable process even over longer periods of operation. In addition, the lenses are resistant to vibration and can be installed on a moving system such as a robot arm. Various evaluations with non-destructive and destructive tests have proven the high quality of the weld seams.

Thanks to the multispot welding head, complicated weld seams are now also feasible in heat conduction joining of plastics and metals. This vastly expands the industry's capabilities because such manufacturing techniques are of enormous importance to the automotive and aerospace industries and other markets. The prototype is very promising and will soon be ready for series production.

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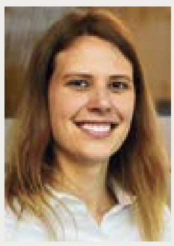

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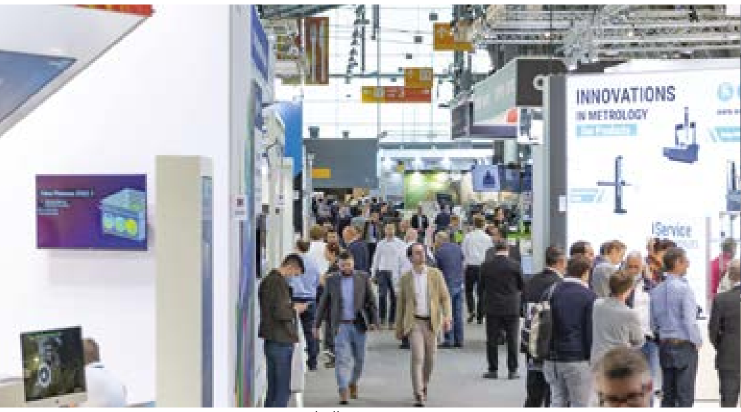

Source: P.E. Schall

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www.euroblech.com

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5th European Machine Vision Forum

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www.emva.org

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www.lafbremen.de

November 30 – December 01, 2022

W3+ Fair Rhine Valley

Dornbirn, Austria

https://w3-fair.com/en/rhine-valley

December 6 – 8, 2022

SPIE Photonex Conference & Exhibition

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https://spie.org

December 6 – 7, 2022

2nd International Conference on Applications of Quantum Technologies QuApps 2022

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https://quapps-conference.com

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https://spie.org/photonics-west

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Read event previews and reviews on www.wileyindustrynews.com/en/events

Basel base of optical connection activity

Review: European Conference on Optical Communication ECOC, Basel, Switzerland, 18 – 22 September 2022

Mid September Basel was an intersection of optical connectivity market analysis, ground-breaking research and the latest products creating a buzz around the city.

The return of ECOC's popular Market Focus sessions was kicked off on Monday with a typically incisive and experienced presentation from Dr Michael Lebby, CEO of Lightwave Logic, alongside VP engineering, Dr John Zyskind on 'Utilizing foundries to scale hybrid electro-optic polymer modulators.'

Later in the morning saw the beginning of the Product Focus sessions, with a presentation from Dr Paul Brooks of Viavi Solutions attended by a packed-out theater. He discussed the challenges that lie ahead for the ecosystem in relation to 800G pluggable.

With the Market Focus sessions keeping their rhythm, speakers from SiFotonics Technologies and HyperLight Corporation lead the way. A short walk away at the Product Focus sessions, tunable lasers and optical fiber in the automotive and industrial sectors were two topics from a strong day of presentations.

Into the afternoon, at Market Focus, Inferia's director of solutions marketing, Fady Masoud, talked about 'Extending Coherent to the Edge with XR Optics'. PICs proved to be a hot topic into the afternoon, with presentations from Ligentec and VLC Phonetics both covering it in their own ways. Sessions from Sivers Photonics and Corning Incorporated closed the day's Market Focus sessions.

Awards took center stage for ECOC Exhibition's second day

Lightwave Logic's Michael Lebby was joined by ECOC TV to dish out a carefully curated selection of categories to deserving winners. From a pool of strong nominations, five companies left the Product Focus theatre this morning with Industry Award trophies in hand.

The Data Centre Innovation Best Product award went to Lumentum for its 200G PAM4 EML chips. Lumensity Limited won the Best Fibre or Fibre Component award for its CoreSmart cable technologies and, for the Most Innovative Product, Ciena took home the award for its WaveLogic 5 Nano PKT-MAX ('Packet-Max').

The Optical Integration award, meanwhile, went to Coherent. The big winner of the morning was Source Photonics, however, as the company received not one, but two awards – for Optical Transport and Innovative FTTx Product.

FTTH Council Europe commenced the morning's schedule before the awards ceremony with a topical talk on the 'state of play of FTTH roll out in Europe'. The rest of the morning and afternoon saw presentations from EXFO, Semtech Corporation, Meta Inc. with a talk on the Telecom Infra Project, and Cognifiber.

The Market Focus across Tuesday's sessions saw varying perspectives on pluggables populate much of the day's schedule – talks on 'Standardized Pluggable v Proprietary Multi-haul', 'evolving to CPO or advancing pluggables', and 'Opportunities for coherent pluggables beyond DCI' came from Acacia, now part of Cisco, Cignal AI, and Omdia, respectively.

Other presentations came from Infinera on pushing coherent to the edge, Effect Photonics on addressing the edge computing and data center infrastructure market, and OIF with a talk titled CMIS – Management Control Optical Modules.

The Basel show closes, but the event carries on!

At their and their partners' and customers' booths, attendees shared a farewell drink, exchanged cards with new contacts, and celebrated the past three days of this year's ECOC Exhibition on the final day in Basel.

Every corner of the exhibition space saw plenty of action over the previous three days – the Market Focus theater was frequently at capacity, sounds of applause from Product Focus could be heard across the hall in appreciation of the technological innovation on show, and demonstrations and meetings at the exhibitor booths contributed to the noticeable buzz at ECOC Exhibition 2022.

Whether it was the ECOC Exhibition Industry Awards, the on-stand demonstrations from the industry's leading countries, or the desire to secure a seat before another packed-out day at the Market Focus and Product Focus theaters, the exhibition hall welcomed another wave of keen optical connection devotees.

Nexus Media Events

Winners of two awards at the Industry Awards ceremony, Source Photonics, kicked off the final day of Market Focus sessions with a presentation entitled 'New optics for 5G and beyond.'

The following presentations came from Coherent, Marvell and OIF with a common theme of optical connectivity and evolution.

Into the afternoon, discussions ranged from the future of satellite connectivity, what the future looks like for apps beyond headsets, to new standards in the automotive world. Featuring talks from Dirk Götzl from Huber + Suhner Cubeoptics, and Mark Lutkowitz from fibeReality, the final sessions of ECOC Exhibition ended on a diverse high.


Source: Nexus Media Events

Wednesday's Product Focus sessions were divided between EPIC TechWatch and Yamaichi Electronics. Contributions to EPIC's talks kept the audience engaged and receptive, with a talk from Francisco Rodrigues, CEO at PICadvanced, brining EPIC's slot to a close on the topic of 'Photonic Integration Based Devices for Tunable and Next Generation Networks Speaker.'

David Binder, business development manager of Yamaichi Electronics wrapped up this year's Product Focus sessions by discussing the ins and outs of the optical module.

You can relive ECOC Exhibition through the virtual catch-up. The event will return next year in Glasgow, Scotland, from 2 – 4 October 2023.

www.ecocexhibition.com

International photonics community back in Franconia

Review: 12th CIRP Conference on Photonic Technologies [LANE 2022], Fürth, Germany, 4 – 8 September 2022

After a virtual edition of the LANE conference in 2020, Bayerisches Laserzentrum (BLZ) and the Institute of Photonic Technologies (LPT) of Erlangen Nuremberg University welcomed more than 300 scientists from 20 countries on-site.

The main aim of the LANE conference series is the exchange of up-to-date scientific results and developments on the application of lasers in research and production, providing a platform for participants from both science and industry. After a plenary session with inspiring keynote talks and the ceremony for the Award of the German Scientific Laser Society WLT, all aspects of laser material processing were presented and discussed in two hundred talks during four conference days. Beyond that, the participants enjoyed the evening events, which framed the lecture sessions, offering various options to chat with old friends and get to know new ones.

The accompanying industrial exhibition with booths of international companies gave conference delegates the chance to discuss their latest research results also from a technical point of view. With the intention to make the people behind the talks and their origin visible on the one hand and draw attention to the very important topic of diversity in science on the other hand, the social media campaign #people@lane was set up in the run-up to the conference. A people@lane lounge completed this new concept on-site.

Conference participants during LANE 2022’s plenary session (Source: LPT / K. Cvecek)

Special highlights were certainly the presentations of different awards to scientists for their extraordinary achievements: Dr Anna Rosa Ziefuß from the University of Duisburg-Essen received the WLT Award 2022 for her outstanding research. Prof Reinhart Poprawe was ennobled as the new “Knight of Laser Technology”. Furthermore, Mirko Sinico (KU Leuven, Belgium) was the winner of the LANE 2022 Best Presentation Award, elected by the conference attendees.

The 13th CIRP Conference on Photonic Technologies [LANE 2024] will take place again in Fürth from 15 – 19 September 2024. The call for papers will start in October 2023.

www.blz.org ▪ www.lpt.tf.fau.de

13 topical meetings, 3 special sessions and 1 exhibition

Review: EOS Annual Meeting EOSAM, Porto, Portugal, 12 – 16 September 2022

This year, the European Optical Society Annual Meeting, EOSAM, took place in Portugal at the faculty of engineering of the University of Porto, FEUP.

The extensive EOSAM 2022 program included thirteen Topical Meetings (TOMs), three special sessions and an exhibition. 360 attendees enjoyed more than 300 presentations during the week.

Plenary session at EOSAM 2022 (Source: EOS)

EOS provided nine tutorials relating to the topical meetings on Monday, 12 September. For the sixth time, EOS organized a special session for EU projects, and nine partners were invited to disseminate their goals and results to the conference audience.

The Early Stage Researcher Session was designed for participants in the first four years (full-time equivalent research experience) of their research careers and who have not been awarded a doctoral degree. Six students made very high-level presentations at the session.

On Tuesday, an industrial optics podium session was held in co-operation with the EOS and EPIC.

Challenges and solutions from companies were highlighted to researchers by Thorlabs, Toptica, Sphere, and GLOPhotonics. Afterwards, a very nice networking reception was enjoyed by all with live music from the faculty TUNA group, together with drinks and snacks.

EOSAM included six fantastic plenary speakers on various topics. The EOS Prize was awarded to the best paper published in the Journal of the European Optical Society.

A two-day exhibition was held with Sphere, Thorlabs, Toptica, GloPhotonics, JEOS:RP and EDP Sciences, with a great buzz at the booths all week.

The welcome reception and all coffee breaks, lunches and the conference dinner, all included in the conference ticket, made sure there was a lot of networking. The conference dinner was held in the magnificent Mosteiro São Bento da Vitória with a full rich history and amazing local delicacies.

The EOS annual general assembly was held on Thursday, 15 September. New fellows were elected, and the newly elected EOS executive committee started their work. The best student presentations were awarded at the end of the conference.

Next year EOSAM takes place in Dijon, France, 11 – 15 September 2023.

www.europeanoptics.org

Preview: 5th European Machine Vision Forum

27 – 28 October 2022, Páirc Uí Chaoimh Stadium, Cork, Ireland

Where research meets industry: "Accuracy, Reliability and Limits of Machine Vision" is the focal topic of the 5th EMVA forum. EMVA's local partner hosting the event is the Tyndall National Institute.

This topic is highly relevant. Research can outline the theoretical limits and detail how far current state-of-the-art industrial solutions are away from the best possible solutions. Industry can contribute with information on the most urgent market demands for better solutions. So the topic is ideal for a dialogue between research and industry to initiate new projects for the development of novel powerful and at the same time cost-effective systems in areas where there is a corresponding market need.

The European Machine Vision Forum is an annual event of the European Machine Vision Association EMVA. The aim is to foster interaction between the machine vision industry and academic research to learn from each other, discuss the newest research results as well as problems from applications, learn about emerging application fields, and to discuss research cooperation between industry and academic institutes.

www.emva.org

Preview: Formnext 2022

15 – 18 November 2022, Frankfurt/Main, Germany

As the leading industry platform for additive manufacturing and industrial 3D Printing, Formnext is the international meeting point for the next generation of intelligent industrial production, in Frankfurt am Main as well as digitally.

More than 700 exhibitors have registered. The exhibitors list, of which almost 60 % are international, is impressive.

Formnext is the place to experience additive manufacturing with all ones senses. Whether one hears the sound of industrial production systems, sees incredible geometries take shape or feels the spirit of an industry that is buzzing with excitement, nobody is able to withstand this energy.

As a reliable partner of the additive manufacturing community, Formnext offers an information hub for professionals interested in additive manufacturing and for AM know-how all year round, AM4U. Whether magazine, TV, technology guide, media library, seminars and webinars, together with our partners we research the latest developments, applications and business opportunities around the process chain of additive manufacturing. Suppliers of various industrial 3D printing solutions can now be found in the AM directory.

https://formnext.mesago.com

Preview: W3+ Fair Rhine Valley

30 November – 1 December 2022, Dornbirn, Austria

W3+ Fair Rhine Valley calls developers, suppliers and users of enabling technology around optics, photonics, electronics and mechanics to the Rhine Valley. W3+ will take place for the third time in the Dornbirn exhibition center along with the accompanying en.tech.talks.

Even more inspiration awaits exhibitors and visitors, as two additional events take advantage of the fair's high-quality high-tech environment: Tech.Con, the platform for industry, commerce and production in the Lake Constance region, will be held simultaneously.

Top-class expertise will be brought along by the University of Applied Sciences of Eastern Switzerland, which is docking its established high-tech conference "Precision Photonic Systems" to the W3+ Fair for the first time, making Dornbirn an information and networking hotspot in the four-country region.

Major companies such as Swarovski, SwissOptic, OptoTech, WZW Optic, APM Technica, the University of Applied Sciences Graubünden, Eplan, Acktar, RhySearch, Laservision, FPM Holding, Victor Kyburz, Chroma Technology, OPC, Polytec, Sensofar and others will exhibit.

Several organizations are supporting the event again: EPIC, Swissphotonics, Photonics Austria, OptecNet Deutschland, Wetzlar Network, Biolago, IVAM, Spectaris, and Hessen Trade & Invest.

https://w3-fair.com/en/rhine-valley

Preview: QuApps 2022

6 – 7 December 2022, online

The 2nd International Conference on Applications of Quantum Technologies will be held virtually via Zoom.

Quantum technology and its applications are gaining relevance for our life day by day. The IVAM Microtechnology Network is going to give experts the opportunity to discover the latest advances in quantum technology and to network closely within the community.

QuApps 2022 will provide information on the latest trends and developments and offer the opportunity to discuss with renowned quantum technology experts. This year, the focus of the conference will be even more concentrated on the application-related capabilities of the innovative developments and ideas. Among others, the following application areas will be covered: medical technology, automotive industry, quantum computing, cryptography, and communication.

https://quapps-conference.com

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www.materion.com/balzersoptics

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Tel. +41(0)71 737 74 00
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info@zuendoptics.com
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Prisms

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Am Fleckenberg 20, 65549 Limburg
+49 (0) 6431 9860 – 0
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Optics Balzers AG
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Windows, optical

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aanders@wiley.com

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sales@evosys-laser.com

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www.lpkf-laserwelding.de

Marking systems

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info@photon-energy.de, www.photon-energy.de

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3D-Laserscanning-Entspiegelungsspray
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info@helling.de

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76337 Waldbronn
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info@polytec.de

Dimensional gauging

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76337 Waldbronn
www.polytec.de
info@polytec.de

Film thickness measurements

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Interferometric measurements

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76337 Waldbronn
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info@polytec.de

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EssentOptics Ltd
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Borovlyany, Minsk region
223053 Belarus
Tel: +375 17 5112025
Email: office@essentoptics.com
www.essentoptics.com

Velocity measurement

POLYTEC GmbH
76337 Waldbronn
www.polytec.de
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Services

Application development/ Application laboratories

Fraunhofer-Institut für Lasertechnik
Steinbachstraße 15, 52074 Aachen
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Optical development and engineering companies

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16 January 2023	Publishing date
12 December 2022	Advertising deadline
15 November 2022	Editorial deadline

Focus: Photonics West

- Spectroscopy
- Laser Sources
- Optical Components

2

5 April 2023	Publishing date
3 March 2023	Advertising deadline
6 February 2023	Editorial deadline

Focus: 20th Anniversary Issue

- Laser Materials Processing
- Optical Measurement
- Industrial Machine Vision

➔ **with Company Profiles**

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20 June 2023	Publishing date
15 May 2023	Advertising deadline
17 April 2023	Editorial deadline

Focus: LASER World of PHOTONICS

- Laser Systems
- Photonics for Quantum Technology
- Ultrashort-pulse Laser Sources

➔ **with Product Reports**

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01 September 2023	Publishing date
01 August 2023	Advertising deadline
05 July 2023	Editorial deadline

Special section: Digital Tools, Design Software and Simulations

- Fibers and Fiber Optics
- Optoelectronics, Silicon photonics, PICs
- Optical Systems and Components

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19 October 2023	Publishing date
15 September 2023	Advertising deadline
21 August 2023	Editorial deadline

Trade fairs
Schweisstec
Blechexpo

- Additive Manufacturing
- Laser Plastics Processing
- Laser Welding und Cutting

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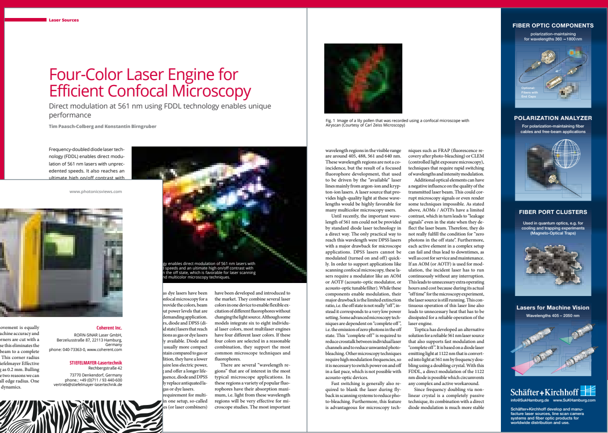
05 December 2023	Publishing date
02 November 2023	Advertising deadline
05 October 2023	Editorial deadline

Focus: Automotive applications

- Lasesr Welding and Cutting
- Beam Forming, Beam Analysis
- Laser Materials Processing



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Addressing the use of a device / technology with a customer / partner. Text: 6,000 to 10,000 characters, 2 – 4 figures including one opening graphic or photography (300 dpi, or vector format)

Product Report

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