Volume 19 August/September 2022

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PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY

COVER STORY

Fixed focal length or telecentric lens?

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CIOE
CHINA INTERNATIONAL OPTOELECTRONIC EXPO

VISION

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DAY OF PHOTONICS

21 OCTOBER 2022

Every company, school, organization, association, university, and individual is invited to participate!

Organise an activity for Day of Photonics!

www.day-of-photonics.org

DAY OF PHOTONICS disseminates "photonics" towards the general public. It is an initiative of EPIC, the industry association that promotes the sustainable development of organisations working in the field of photonics. EPIC fosters a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement.

EPIC
European Photonics Industry Consortium

Switzerland welcomes a major event

ECOC conference and exhibtion to be held in Basel, 18 – 22 September 2022

Every fall, industry leaders and scientists in optics and communications gather at the European Conference on Optical Communication ECOC. It is one of the largest events of science and industry in said field and it typically attracts 4,000 to 5,000 attendees from around the world. The meeting serves the industry to showcase the latest developments and it is the anchor meeting for scientists working in the field.

This year's ECOC, to be held in Basel, Switzerland, gives insights into future trends in the field of 5G/6G, on terahertz communications, machine learning or free space optics. It features latest developments in integrated optics, plasmonics or the cointegration with electronics.

ECOC has a long tradition. The first meeting was held in 1974, triggered by the first experimental demonstration of optical fibers with loss below 20 dB/km in 1970 by the Corning team of Donald Keck, Robert Maurer, and Peter Schulz. ECOC has been held ever since, in yearly conferences. In the meantime, more than five billion kilometers of fiber (33 times the distance from earth to sun) have been deployed, a number that gives testimony to this game changing technology that has paved the way for today's internet and personal communications. As the innovation continues, meetings such as this one are needed to report on breakthroughs and novel applications in optics and communications.

The conference part is going to be opened by five exciting plenary speakers and extends even beyond its pre-Covid full programme with workshops, invited talks, tutorials, and regular papers. A special highlight is the postdeadline paper session on Thursday. It is the annual competition for a presentation slot in the most prestigious session. Only a limited number of slots will be reserved for the latest and best work in the field. ECOC 2022 also is an opportunity to get in-depth training in key fields by means of short courses. Last but not least, a rump session on "Megatrends or No-Megatrends" invites attendees to a vivid controversial discussion.

The conference also runs alongside the ECOC exhibition which brings you over 250 exhibitors. Highlights this year include live market focus presentations, product demonstrations, a job wall, and an industry award ceremony. The event will once again be a meeting place, knowledge center, and platform to showcase the latest optical technology as innovators, thought leaders, and global companies arrive in the city of Basel.

Yours truly

Dr Christoph Harder
President
SwissPhotonics
General Co-Chair
ECOC 2022
CEO
Harder & Partner

SWISS PHOTONICS

ECOC 2022 BASEL

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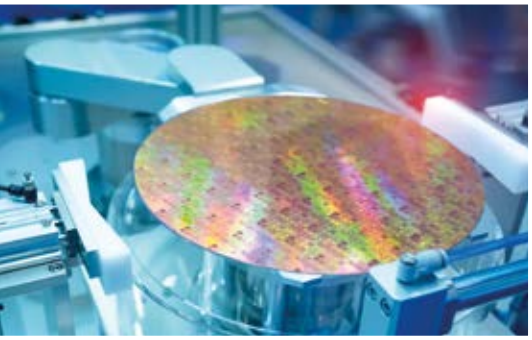

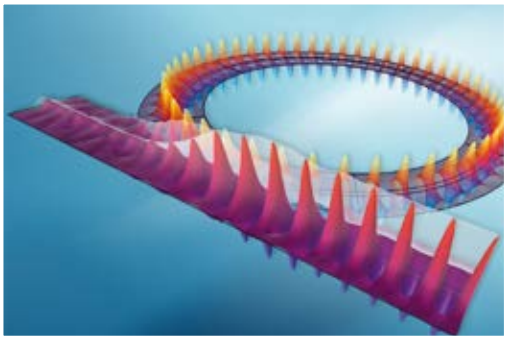

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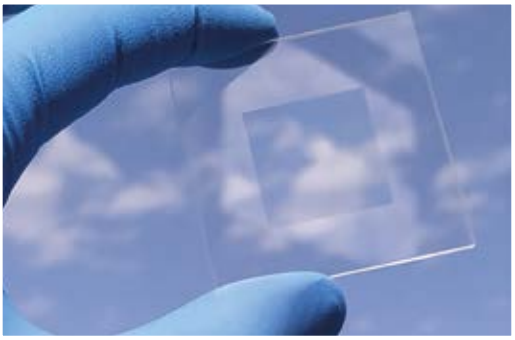

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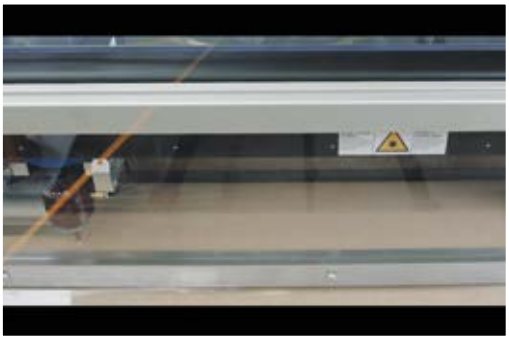

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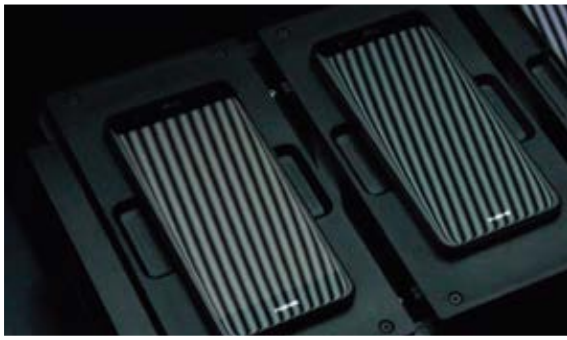

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The article "X-ray emissions during laser machining of cylindrical microcomponents" by Roswitha Giedl-Wagner and Thomas Lang will be published in a future issue.

Cover:

In optical metrology applications, telecentric lenses – in contrast to fixed focal length lenses – have the advantage that they provide accurate measurement results that are independent of the distance to the object being measured.

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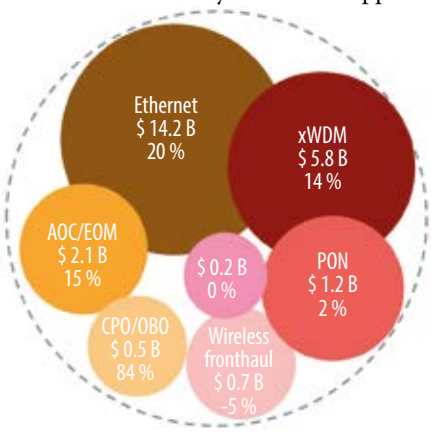
Optical transceiver industry: new applications drive expanding data center infrastructure

For each decade over the past fifty years, there have been new mobile technology innovations. Mobile bandwidth requirements have evolved from voice calls and texting to UHD1 video and a variety of AR/VR2 applications. Despite the profound implications of the Covid-19 outbreak for the telecom infrastructure supply chain, consumers and business users worldwide continue to demand new networking and cloud services.



Growth forecast by datacom application for 2027. Pink: Wireless mid/backhaul (Source: Yole Intelligence)

In this context, Yole Intelligence, part of Yole Group, now offers a specific focus on the optical transceiver industry with a dedicated report to provide a complete analysis of optical transceiver applications, markets, and technologies.

Dr Martin Vallo, senior analyst photonics, asserts: "Revenue generated by the optical transceiver market reached around US$ 10.4 B in 2021 and is expected to reach $ 24.7 B in 2027, which is a 15 % CAGR. This growth is driven by high volume adoption of high-data-rate modules above 400G by big cloud service operators and national telecom operators requiring increased fiber-optic network capacity."

The evolution of multiple technologies has enabled data rates of 400G, 600G, 800G, and beyond across data center infrastructure and in long-haul and metro networks. 400 GbE deployments are ramping across data center networks. Many cloud providers and telecom operators are now starting to deploy an 800 Gbps optical ecosystem to increase bandwidth capacity and keep pace with the growing demand for data. Today's modern Ethernet-switch ASICs providing 25.6 Tb/s total capacity are running at a 50 Gbps SerDes lane rate driven by 50G PAM-4 modulation technology. The next generation of ASIC8 chips expected in 2023 will provide 51.2 Tb/s total capacity and run at a 100 Gbps SerDes9 lane rate. This significantly simplifies electro-optic conversion within the switch system and accelerates the exchange of high-speed optical modules.

Yole Group collaborates with CIOE to organize the highly exciting Forum on Optical Transceivers and Silicon Photonics. It will take place on September 8, 2022, in Shenzhen, alongside the 24th CIOE.

www.yolegroup.com

Baumer builds Innovation Center in Switzerland

At its headquarters in Frauenfeld, Switzerland, Baumer is currently building a new, modern development center for SFR 20 M. After the High-Tech Center in Stockach in southern Germany – opened in 2018 – the new building is the second major investment within a few years.

Model of the new building (Source: Baumer)

The new building will offer the expanding high-tech company 5,000 square meters of additional, state-of-the-art office space for around 120 employees. Oliver Vietze, CEO of the Baumer Group, attaches great importance to the energy concept, which marks a further step towards CO_2 neutrality. "The Innovation Center should become a showcase project, especially in terms of sustainability and energy efficiency," said Vietze.

A complete solar building shell will generate electricity. Using geothermal probes and a heat pump, Baumer heats the interior in winter and cools it in summer for optimal working conditions. In addition, as part of its "Baumer Blue" sustainability initiative, Baumer only uses CO_2-neutral electricity from Swiss hydropower and thereby ensures a clean energy supply at the Frauenfeld site.

www.baumer.com

"The art of making lenses" – Satisloh celebrated its 100-year anniversary

Founded by Wilhelm Loh in 1922 in Wetzlar, Germany, Satisloh is a global provider in ophthalmic and precision optics manufacturing machines. The organization has played a key role in bringing innovations and technologies to both markets during the past one hundred years.

In the aftermath of World War I, the company started producing machines for canning jars, and cast iron lapping tools for numerous local optical factories. Since these humble beginnings, Satisloh has shaped the present landscape of optical manufacturing and is continuing to create the future of lens processing.

Even though the company was founded one hundred years ago, the vision remains the same: with customers at the center of everything they do – improving their customer's production with custom processes and manufacturing solutions. They continue to drive innovation and development with new sustainability technologies, automation, equipment, consumables and processes.

"Celebrating our 100th anniversary is an exciting milestone for the company and our employees. It is also an opportunity to thank everyone who has been on this incredible journey with us – our customers, suppliers, business partners, and the extended Satisloh family. Your support helped us reach this milestone," said Group CEO Bruno Fischer.

The celebrations have kicked off on March 23rd at Satisloh locations across the world. The anniversary will be recognized throughout 2022 at tradeshows and events worldwide for both customers and employees. Satisloh's 100th year will culminate with a celebratory global Satisloh Users Group Festival from 4 – 6 October 2022 in Wetzlar, Germany – right where its story began.

www.satisloh.com

II-VI completes the acquisition of Coherent

Effective July 1, 2022, II-VI Inc. completed the acquisition of Coherent Inc. Under the terms of the merger agreement, each share of Coherent common stock was converted into the right to receive $220.00 in cash and 0.91 of a share of II-VI common stock.

Dr Vincent D Mattera Jr, chair and CEO of II-VI, said "I am also very excited to announce a new direction for our brand: we plan for the combined company to be named Coherent. We will soon announce the date of the launch of our new brand identity. While the name Coherent has a strong association with lasers, the broader meaning of the word is 'bringing things together'. It represents our diversity in thinking, distilled into our clarity of purpose, our unity in action, and our broader sense of engagement."

The combined company will serve the four markets of industrial, communications, electronics, and instrumentation, which together represent a fast-growing total addressable market of $ 65 B. Its global workforce is comprised of over 28,000 associates in 130 locations.

II-VI will continue to be led by a proven leadership team that maximizes the strengths of the combined company, and will maintain the board of directors comprised of seasoned executives and thought leaders from highly diverse industries. Stephen A. Skaggs and Sandeep S. Vij, former directors of Coherent, join the board.

The combined company will be organized into three business segments. Dr Giovanni Barbarossa will continue to serve as the chief strategy officer of the company and lead the materials segment, previously referred to as the compound semiconductors segment. Sunny Sun will continue to lead the networking segment, which was previously the photonic solutions segment. Dr Mark Sobey, formerly the COO and executive vice president of Coherent, will be the president of the new lasers segment.

II-VI / Coherent / Wiley

https://ii-vi.com
www.coherent.com

Lumibird completes takeover of Saab's defense laser rangefinder business

The transaction, which was signed in March 2021, was subject to a number of conditions, all of which were fulfilled by the end of May. As part of the transaction, 27 Saab employees in Gothenburg will be transferred to the newly-established subsidiary Lumibird Photonics Sweden AB. The divested operations had revenues of around ten million euros in 2021.

The acquisition of this business, which Lumibird has known as a key component supplier for Saab for over fifteen years, represents a first step towards a consolidation of the European defense lasers and rangefinders market.


Source: Saab

Vidar laser rangefinder

www.lumibird.com

Customized optics individually developed

Vision & Control now also offers the development of individual optics for customized applications in optical machine plant monitoring. Together with the customer, optical designers and engineers create a complete solution from the specifications to delivery with test report – all in a closed technology chain. During development, the experts use software systems such as Zemax and Inventor. Development and production take place in-house in Germany within the framework of ISO-certified processes. By working with regional suppliers, there are no delays in prototyping or spare parts availability.


Source: Vision & Control

www.vision-control.com

Olympus spins-out scientific solutions business under the name Evident

Following the divestiture of its imaging business, the move to split the industrial and life science businesses from medtech further signifies the company's long-term strategy to cement its position as a major player in the medtech industry. The proposed split was first announced in June 2021. As a newly-established wholly-owned subsidiary, Evident, headquartered in Japan, continues to operate independently under the Olympus umbrella.

The scientific solutions business encompassed the company's industrial and life science businesses. The reorganization will give the scientific solutions business the autonomy and agility to respond quickly and more flexibly to the needs of its customers.

Yoshitake Saito, president and representative director of Evident, commented on the new focus: "Evident, while continuing to provide best-in-class products, will expand its digital and cloud-based solutions to enhance the customer experience and to improve the overall workflow in the research and inspection fields. We will shift from a business model centered on the sale of products, to one focused on solving customer issues and challenges. With this greater management autonomy, we will promote agile product development and open innovation, which we believe will increase the speed of product development."

"The new company name exemplifies our unwavering commitment to continue providing high-quality products and technical expertise, allowing our customers to discover new insights and find new evidence in their areas of expertise, and a renewed focus on customer collaboration and responsiveness to customer concerns."

www.olympus-global.com
www.evidentscientific.com

More production capacity for the world's smallest lenses

GD Optical Competence GmbH is investing around six million euros in its new production and administration site in the community of Sinn. On May 6, the groundbreaking ceremony took place for the construction of the company's 2,000 m² new production facility.


Source: GD Optics, J. Wolz

Right to left: Gerhard Dross, Hans-Werner Bender, and Winfried Czilwa

With a view to the positive development of the past years and the goal of further driving the sustainable transformation of the company, the management and shareholders have decided in favor of a new building on a greenfield site. This creates the best conditions for the company to pursue the growth course described in the corporate strategy. A well thought-out sustainability strategy of GD Optics rounds off the package fit for the future.

At its new address "Zur Dornheck 24 in 35764 Sinn", the company also takes into account the aspect of work-life balance with generous green spaces. In addition to doubling the production area, in which the special growth area of micro-optics was taken into account, the capacity for optical coatings can also be doubled. The diameter of the smallest lens in the world produced by GD Optics is only a fifth of a millimeter.

The focus of the company's growth is on quickly adaptable capacity, short response times to customer requests and the production of large quantities.

https://gdoptics.de

PI creates space for manufacturing capacity

Physik Instrumente (PI) has acquired an additional building in the immediate vicinity of its headquarters, into which various global corporate functions are moving. This will free up around 1,000 m² of space for production at the main building.


Source: PI

PI's additional building

The additional investment of around 10 million euros for the acquisition of the building and conversion and expansion work complements the global investment package of 53 million euros already launched in 2021 for further capacity expansion.

PI is also pushing ahead with capacity expansion at the Eschbach and Lederhose sites in Germany and at its international locations. The expansion of the workforce is also well underway. As of the end of June, almost 100 of the additional 240 positions planned in Germany for 2022 have now been filled.

The company had already increased capacity by around 30 percent in 2021 and hired more than 170 new employees. All investments are the result of the "Maximum on-time Delivery" initiative with which PI is systematically improving its delivery capability.

www.physikinstrumente.com

Trumpf reinvests in software companies

The decision to acquire outstanding shares in a joint venture and invest in cloud platform programming experts are prompted by the machine tool and laser maker's ongoing digitalization strategy.


Source: Trumpf

ScaleNC offers digital services

ScaleNC is a startup that offers digital services on a cloud platform to sheet metal manufacturers, for example, to program their machines. The enterprise intends to use this investment to fuel growth in Germanophone countries and branch out its services to customers in the US. The wholly-owned Trumpf subsidiary not only uses AI and data-based algorithms for the subsequent programming; experienced CAD/CAM specialists also double-check the programming.

Trumpf has also acquired the remaining 49 percent of the shares in Indian software developer Trumpf Metamation Pvt Ltd. The firm in Chennai, which specializes in the development of CAD and CAM software applications and machine control solutions, is a key component of Trumpf's global software strategy. It offers excellent conditions for further growth thanks to Chennai's established cluster of international software firms.

www.trumpf.com

DPE acquires majority stake in Sill Optics from Pinova

Sill Optics is a leading manufacturer of precision optics used in laser material processing, additive manufacturing, medical technology and accompanying chip manufacturing processes, among others. Pinova had taken over the company from its former owners in 2019 and successfully developed it. Under the leadership of Christoph Sieber, investments in recent years have included coating and clean room technology, and the management team has been broadened to equip Sill Optics for further growth. Sieber remains a major shareholder under DPE together with CFO Benjamin Sauter.


Source: Sill Optics

Christoph Sieber (l.), Benjamin Sauter

With around 250 employees, Sill Optics develops and manufactures in Wendelstein. Herbert Seggewiß, partner at Pinova, stated, "In recent years, Sill Optics has been able to develop significantly in terms of more modern production processes, reorganization of the entire company and expansion of sales, so that the company is very well positioned for the next growth step."

"Optical components and systems are used in a wide range of rapidly growing applications. We are pleased to support Sill Optics, a strong player in this attractive market, on its further growth path," said Fabian Rücker, partner at DPE.

www.silloptics.de

Quantum technology for everyday use compact sensors

The new Jena University junior research group 'Integrated Quantum Systems' will receive funding worth more than three million euros over five years from the German Federal Ministry of Education and Research. The funding confirmation arrived this week and the group will start its work immediately. The five scientists are taking on the task of testing and proving the suitability of modern quantum technologies for everyday use.

"We'll break new ground in order to transform laboratory setups into everyday technology," says Dr Tobias Vogl, outlining the aim of the working group. The thirty-year-old scientist from the institute of applied physics at the University of Jena, Germany, heads the new junior research group. "We consider the combination of solid-state photonics and quantum materials to be particularly promising," he adds.

The new group will focus its research in particular on the properties and possible applications of boron nitride.

www.uni-jena.de

Tobias Vogl aligns a quantum light source's optical chip (Source: U Jena / Jens Meyer)

Quantum computing: consortium receives 50 million euros in funding

A consortium led by quantum start-up Q.ant is set to receive some 50 million euros in research funding. Approximately 42 million euros of this will come from the German Federal Ministry of Education and Research (BMBF), while the consortium partners will contribute around 8 million euros.

The funding will be used to construct a demonstration and test system for quantum computer chips and other quantum computer components. This will enable the consortium to conduct research into algorithms and technologies for photonic quantum computing and prepare for industrial scale-up.

Q.ant, a wholly owned subsidiary of Trumpf, recently presented a method that could be used to fabricate extremely powerful quantum computer chips. By creating highly specialized optical channels on silicon chips, this photonic chip process is able to transport, control and monitor quanta with virtually zero loss, even at room temperature.

Source: Trumpf

A Q.ant employee holds up a wafer from which photonic chips are cut.

The "PhoQuant" consortium involves a total of 14 partners from academia and industry, among them: Q.ant, HQS Quantum Simulations, Swabian Instruments, TEM Messtechnik, Ficontec, and Menlo Systems.

https://qant.de

European supply chain for diamond-based quantum technologies

The GrodiaQ project consortium (short for: large area diamond substrates for quantum technology) has started its work to ensure the availability of high-purity as well as large area diamond wafers for quantum technology applications. The consortium is coordinated by the Fraunhofer Institute for Applied Solid-State Physics IAF and consists of a further five companies with their own expertise in manufacturing, processing and utilization of diamond and diamond-based quantum technologies.

Together, the project partners cover the entire value chain. The aim is to develop manufacturing equipment and basic materials for quantum devices that can be commercially exploited by the industrial partners at the end of the project. The German Federal Ministry of Education and Research (BMBF) is funding the project for three years.

In three steps, GrodiaQ wants to enable industrially usable diamond substrates and thereby lay the foundation for a European supply chain for quantum devices. Diamond Materials is responsible for grinding and polishing. Evatec Europe is designing and constructing an energy-efficient reactor for chemical vapor deposition which, in combination with new semiconductor microwave generators from Trumpf Hüttinger, is intended to achieve industrial standards for wafer coating from sizes of four inches.

Finally, the associated partners Q.ant and Quantum Brilliance will evaluate the substrates.

www.iaf.fraunhofer.de

Ribbon-cutting ceremony for Advanced Photon Source's new facility

US Secretary of Energy Jennifer Granholm and several Illinois leaders cut a ceremonial ribbon on Monday to mark the completion of a new facility to host new experiments that will contribute to the future of electric vehicles, quantum computers and resilient materials for all kinds of uses.

The newly constructed Long Beamline Building (LBB) at the US Department of Energy's (DOE) Argonne National Laboratory is an experiment hall that will become a part of the Advanced Photon Source (APS), a DOE Office of Science user facility. It will house two new beamlines that will transport ultrabright X-rays from the heart of the APS to cutting-edge scientific instruments.

This next generation of beamlines will be capable of providing high-resolution X-ray images of critical components and technologies from aircraft engines to solar cells to advanced materials for microelectronics, in clear detail and at impressively small scale.

Source: ANL

(l – r) Laurent Chapon, US Rep. Bill Foster, Elmie Peoples-Evans, Secretary Granholm, State Sen. Diane Pappas, Jim Kerby, ANL director Paul Kearns, DOE Office of Science ASO deputy manager Rock Aker, US Rep. Bobby Rush, and State Sen. Sue Rezin

The LBB is part of an 815 million dollar upgrade of the APS, one of the most productive X-ray light sources in the world.

www.anl.gov

Pruuve wins Photonics21 Innovation Award 2022

Tim Achenbach, Paul-Anton Will and Philipp Wellmann started the TU Dresden spin-off Pruuve in May 2022 with the aim of bringing reusable UV sensor foils to market maturity. Now they have been honored with the Photonics21 Innovation Award.

Source: Babylonia, T. Monasse

Tim Achenbach (left), Photonics21 president Dr Lutz Aschke

On June 30, 2022, Photonics21 hosted the "Photonics Partnership Annual Meeting" in Brussels. More than 300 guests, including CEOs, heads of research institutions and representatives of the European Commission and EU member states, came to the event. Dresden physicist Tim Achenbach represented the Pruuve team and was given a very special honor: the Photonics21 Innovation Award, which is intended to push for more entrepreneurship in photonics.

In their Phosphorescent Response Under UV Excitation project – Pruuve – the three physicists are developing UV sensor foils for the precise measurement of the UV dose in industrial applications, such as the sterilization of air, water and surfaces or for the rapid curing of coated surfaces, printing inks, paints or adhesives. The foils are directly attached to the surfaces or components to be irradiated, where they enable visual control of the UV dose. The new technology provides fast and reliable control of the success of UV curing and UV disinfection, thereby avoiding unnecessary waiting times and overdosing.

"We are convinced of our versatile Pruuve technology and will develop new applications and products in the coming years," added Dr Wellmann.

www.pruuve.de

Helmholtz Prize for two world-class optics research teams

Source: PTB / WE Heraeus

(l. to r.) Prof Cornelia Denz (PTB), Drs. Nathalie Picqué and Edoardo Vicentini (MPQ), Karl-Peter Lallmann (Helmholtz Fonds)

Europe's most important award for precision measurement went to researchers in Düsseldorf and Garching, honoring two important contributions to physics, one relating to fundamental research and one to applied research, but both in the field of optics.

In the fundamental research category, the prize goes to Soroosh Alighanbari and his colleagues in Prof Schiller's research group at the Heinrich Heine University Düsseldorf for the development of a new method of precision spectroscopy to explore fundamental questions of physics.

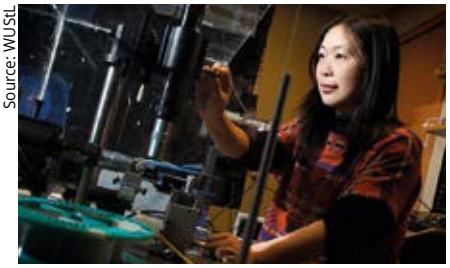
The Helmholtz Prize in the category of applied metrology has been won by Nathalie Picqué and Edoardo Vicentini of the Max Planck Institute of Quantum Optics MPQ in Garching. Their work has significantly expanded the capabilities of digital holography through the use of frequency combs.

The awards ceremony for both prizes, each endowed with 20,000 euros, was held on 12 May 2022 during the international conference on "High-Precision Measurements and Searches for New Physics". This conference was organized as a Wilhelm and Else Heraeus Seminar and took place at the Physikzentrum in Bad Honnef, Germany.

www.ptb.de

Yang wins German research award

Source: WUStL



Lan Yang in her micro/nano photonics lab

Lan Yang, at the McKelvey School of Engineering at Washington University in St. Louis, has been selected to receive the Friedrich Wilhelm Bessel Research Award.

Yang, the Edwin H & Florence G Skinner Professor in the Preston M Green Department of Electrical & Systems Engineering, was chosen for the award in recognition of her academic record. She has been editor-in-chief of the journal Photonics Research since 2019 and is a fellow of several scientific organizations, including the American Physical Society.

Lan Yang is listed as one of the mostcited researchers in her field; her work has been cited nearly 17,500 times, according to Google Scholar.

Yang, who researches tiny photonic devices with unusual properties for controlling light, is invited to collaborate with specialists in Germany as part of the award.

The Bessel Award, given by the Alexander von Humboldt Foundation, was created to sponsor distinguished scientists in any discipline.

https://wustl.edu

inspect award 2022: vote now and choose the best innovations

The jury of the inspect award 2022 has nominated ten products each in the categories 'Vision' and 'Automation + Control'. Now it is the turn of the readers of the magazines under the WileyIndustryNews.com portal to choose the best innovations in machine vision and optical metrology of 2022.

Nominated companies are Automation Technology, Baumer, CBC Europe, Chromasens, Edmund Optics, Lucid Vision Labs, Matrix Vision, Nerian Vision, SVS-Vistek, Vision Components, Aerotech, Göpel Electronic, Micro-Epsilon, Octum, Opto, Tordivel, and Visiconsult.

The voting of the inspect award 2022 runs until September 23, 2022. Vote here:

www.inspect-award.com

New manager of Egide's Bollène site

David Hien was director of business development for Europe and Asia. In April he succeeded Eric Delmas, who has decided to pursue his career outside the group.

Jim Collins, president and CEO of the Egide group, comments, "I would like to thank Eric for his contribution to the management of the group as deputy CEO and as manager of the Bollène site. Since 2018, under his leadership, Egide has taken on a new dimension. We are pleased with the appointment of David Hien to assume the management of the Bollène site. David already manages the sales force directly, in addition to the business development and strategy part which he still manages. With full responsibility for the Bollène production site, he now has all the cards in hand to focus on customer satisfaction and new technological partnerships."

Source: Egide Group

David Hien

Hien is a graduate engineer from the École d'ingénieurs des Hautes Technologies et du Numérique. He is an expert in business development and marketing in the field of electronics and has worked for Texas Instruments in Europe, Taiwan and Dallas, as well as for Dekra in Spain. He joined the group in May 2021 as business development director for Europe and Asia.

www.egide-group.com

Imint appoints Nils Hulth as CPO

Seasoned technology executive to spearhead all aspects of product and portfolio management: Imint Image Intelligence AB, provider of video enhancement software, has named Nils Hulth as the company's new chief product officer, reporting directly to company CEO Andreas Lifvendahl.

Nils joins Imint after a successful 16-year tenure at Pricer, a global technology company serving the smart retail market, where he held a wide range of senior-level roles across product development, sales management, and business development. In January 2020, Nils was appointed as company's CPO.

As Imint's CPO, Nils will spearhead all aspects of product management, and is thus responsible for the company's present and future Vidhance portfolio. Additionally, Nils will accelerate the company's growth through increased efforts in product discovery and business development.

Source: Imint

Nils Hulth

Since its inception, Imint has generated significant and sustained growth within its core mobile market. The company pushes the boundaries of smartphone video enhancement performance, while also productizing new solutions for wearables, AR headsets, body-worn cameras, and more.

https://weareimint.com

CFO Hans-Dieter Schumacher will leave Jenoptik after the expiry of his contract

Source: Jenoptik

Hans-Dieter Schumacher

Hans-Dieter Schumacher (58) has notified the supervisory board that, for personal reasons, he will not be available for a further term after his current contract expires in March 2023. Schumacher joined Jenoptik as chief financial officer on April 1, 2015. Prior to this role, he was CFO of the Homag Group from 2011 to 2015 and CFO of construction material manufacturer Sto from 2003 to 2010.

Within the Jenoptik board, Schumacher is responsible for finance and controlling, treasury, taxes, IT and data security, internal audit, corporate real estate management, and strategic procurement. He played an active part in transforming Jenoptik into a global photonics company and facilitated the financial latitude required to ensure the strong growth seen in recent years with pioneering investments and acquisitions. Jenoptik was also one of the first companies to switch over to sustainable group financing and in 2021 successfully placed debenture bonds and a syndicated loan on the market, both of which are linked to sustainability targets. Under his leadership, data and processes were harmonized worldwide thanks to a standard SAP S/4 Hana system, which will go live this summer.

A successor will be announced in due course.

www.jenoptik.de

Change in the Carl Zeiss executive board – Matthias Metz leaves for BSH

Source: Zeiss

Susan-Stefanie Breitkopf, Dr Matthias Metz, Sven Hermann (l. to r.)

Carl Zeiss is expanding its executive board to include the position of chief transformation officer (CTO), for which Susan-Stefanie Breitkopf (53) has been appointed. She has been head of corporate human resources since 2021. Previously, she was managing director and labor director at the Currenta Group. Before her career in industry, Breitkopf, who has a degree in law, worked as a specialist attorney for labor law.

Dr Matthias Metz (51), on the other hand, has decided to step down from the executive board. He has been a member of the management board since June 2015 and is responsible for the consumer markets division. He will take over as CEO of BSH Hausgeräte on October 1, 2022.

He will be succeeded by Sven Hermann (47), effective July 1, 2022. Hermann is currently chief sales and marketing officer of the Zeiss vision care business unit. In 2014, he became CFO of the Zeiss vision care division and has been chief sales and marketing officer since 2015.

www.zeiss.de

New CIE report on spectroradiometry

Under the scientific direction of Instrument Systems, the Technical Committee TC2-80 of the CIE has prepared a new technical report on the spectroradiometric measurement of optical radiation sources. The document, published as

CIE 250:2022, supersedes the almost 40-year-old report CIE 063-1984. Practically oriented, it contains basic measurement principles and practical instructions for the spectroradiometry of optical radiation sources in the wavelength range 200 – 2500 nm. It is primarily concerned with the measurands irradiance, radiation density, radiation intensity and radiant flux, together with the quantities derived therefrom. In addition, it provides a detailed overview of the physical effects relevant to the estimation of measurement uncertainties. The report offers a comprehensive insight into the relevant terminology and the fundamentals of calibration of spectroradiometric measuring instruments as well as the identification, understanding and quantification of the relevant components of measurement uncertainty. Technical Report CIE 250:2022 can be purchased in the CIE online shop: www.techstreet.com/cie.
As one of the leading manufacturers of light measurement technology, Instrument Systems has attached particular importance to the metrological traceability of measurement results, and offers calibrated instruments with high absolute measurement accuracy. At the Light+Building event in October 2022, the company will present a choice of high-precision and traceably calibrated light measurement systems.

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Light+Building, Frankfurt, Hall 8.0, Booth H38

Femtowatt photo receivers as an alternative to PMT and APD

Manufacturer: Femto Messtechnik
Product: extremely low-noise photo receivers of the 'FWPR-20' series for the wavelength range from 320 nm to 1700 nm and 20 Hz bandwidth with integrated signal amplification up to 10^{12} V/A.
Features: the femtowatt photoreceivers combine comparatively large-area Si-PIN or InGaAs-PIN photodiodes with extremely low-noise transimpedance amplifiers. The NEP is only 0.7 fW/√Hz and enables direct measurement of optical power down to the femtowatt range with a digital voltmeter. In combination with a lock-in amplifier, modulated AC measurements down to the sub-femtowatt range can also be easily implemented. The photo receivers feature high quantum efficiency, robustness against optical overload and a compact design, making them a good alternative to photomultipliers (PMT), avalanche photodiodes (APD) or cooled germanium detectors in many

applications. In non-time-critical applications with acquisition times of more than 100 ms, the photoreceivers even achieve better noise values than many APD receivers because the excess noise factor, which is unavoidable in APDs, does not occur.
The free space models with a 1.035"-40 thread (FST) are very versatile as they can be converted into a fiber-coupled model very quickly.
Applications: the applications include sensitive measurement of small optical signals in spectroscopy, electrophoresis, chromatography, fluorescence measurements and the replacement of photomultipliers (PMTs), avalanche photodiodes (APDs) and liquid nitrogen-cooled germanium detectors.

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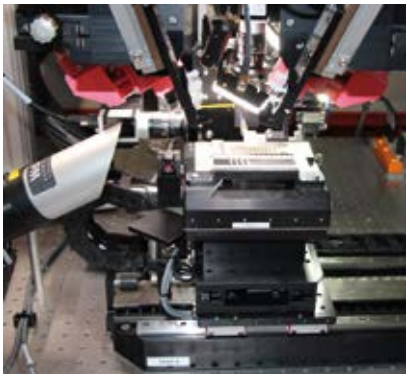
Automated challenging manual assembly processes

Manufacturer: Nanosystec
Product: semi or fully automated production system VersaHybrid with customized hardware and software for complex assemblies that require a precision in the low micrometer regime.



Features: various processing methods are combined into one station. Assembly techniques include micro welding, selective soldering by laser or hot bar and gluing (with subsequent UV or thermal curing) plus laser fine cutting. The large work area accommodates several processing stations with different joining and ablation methods. In this way, a complete device can be built up step-by-step without operator intervention. Feeders, belts and robots facilitate full automation while exchangeable grippers provide high versatility.

The motion system consists of high-precision stages with linear bearings, linear or brushless DC servo motors and optical position feedback. Rotary stages, curved rails and goniometers complement the linear motion to enable adjustment capability in all degrees of freedom. An optional gantry configuration provides superior repeatability over the entire work surface.
High resolution machine vision and multicolor LED illumination support the various process steps. Device-specific algorithms consist of a combination of multiple process steps (e.g. pattern matching, circular detection and edge detection), providing high recognition rates and minimizing process time.
The assembly techniques are determined by the requirements of the device. For instance, a component can be selectively soldered by laser onto a PC board, in the next step another part is laser welded and glued to it. In the last step, laser cutting will be used to remove fine supporting structures.

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Fiber coupler and fiber collimator with mini AVIM connector

Manufacturer: Schäfter+Kirchhoff
Product: fiber coupler series v and fiber collimators series '60FC' with a mini AVIM connector, their first ever commercially available devices worldwide. This opens up new fields of application in the areas of avionics and space as well as ultra-compact and stable instruments.
Features: the mini AVIM connector by Diamond is a world renowned standard for fiber cables. The new mini AVIM fiber coupler and collimator series are compatible with fiber connectors of both types, mini AVIM and midi AVIM. Both series continue to offer the same excellent features, including high pointing stability and long-term stability, which have been proven over the years.
Both the '60SMF' and '60FC' series are available in a large number of focal lengths and numerous different optics types (aspheres, monochromats and achromats) as well as with different AR-coatings.

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Photonic amplifiers reach commercial performance

New device based on silicon nitride photonic integrated circuits generates a record output power

An erbium-doped waveguide amplifier on a photonic integrated chip. (Source: N. Ackerman, LPQM, EPFL)

Erbium-doped fiber amplifiers (EDFAs) can provide gain to the optical signal power in optical fibers, often used in long-distance communication fiber optic cables and fiber-based lasers. Invented in the 1980s, EDFAs are arguably one of the most important inventions, and have profoundly impacted our information society, replacing electrical repeaters.

What is interesting about erbium ions in optical communications is that they can amplify light in the 1.55 mm wavelength region, which is where silica-based optical fibers have the lowest transmission loss. Already in the 1990s, Bell Laboratories were looking into erbium-doped waveguide amplifiers (EDWAs), but ultimately abandoned them because their gain and output power could not match fiber-based amplifiers, while their fabrication does not work with contemporary photonic integration manufacturing techniques.

Now, researchers at EPFL led by Tobias Kippenberg have built an EDWA based on silicon nitride (Si_3N_4) photonic integrated circuits of a length up to half a meter on a millimeter-scale footprint, generating a record output power of more than 145 mW and providing a small-signal net gain above 30 dB, which translates to over 1000× amplification in the telecom band in continuous operation. This performance matches the commercial, high-end EDFAs, as well as state-of-the-art heterogeneously integrated III-V semiconductor amplifiers in silicon photonics.

"Operating with high output power and high gain is not a mere academic achievement; in fact, it is crucial to the practical operation of any amplifier, as it implies that any input signals can reach the power levels that are sufficient for long-distance high-speed data transmission and shot-noise limited detection; it also signals that high-pulse-energy femtosecond-lasers on a chip can finally become possible using this approach," says Kippenberg.

The work signals a renaissance of rare-earth ions as viable gain media in integrated photonics, as applications of EDWAs are virtually unlimited, from optical communications and lidar for autonomous driving, to quantum sensing and memories for large quantum networks.

Reference: *Y. Liu* et al.: A photonic integrated circuit–based erbium-doped amplifier, Science **376**, 1309 (2022); DOI: 10.1126/science.abo2631

www.epfl.ch

A new kind of efficient optical switch

Non-volatile switch manipulates light through the use of phase-change material and graphene heater

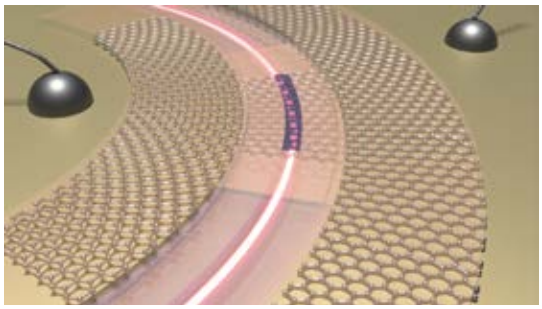


Illustration of a silicon-based switch that manipulates light through the use of phase-change material and graphene heater. (Source: Z. Fang)

One way to reduce energy consumption in data centers is to use light to communicate information with electrically controlled optical switches controlling the flow of light, and therefore information, between servers. These optical switches need to be multifunctional and energy-efficient to support the continued expansion of data centers.

Now, a team led by University of Washington scientists has developed an energy-efficient, silicon-based, non-volatile switch that manipulates light through the use of a phase-change material and graphene heater. "This platform really pushes the limits of energy efficiency," said UW associate professor Arka Majumdar. "Compared with what is currently being used in data centers to control photonic circuits, this technology would greatly reduce the energy needs of data centers."

Traditionally, silicon photonic switches have been tuned through the thermal effect, often by passing a current through a metal or semiconductor, to change the optical properties of a material in the switch, thus changing the path of the light. However, not only is this process energy-inefficient, but the changes it induces are not permanent. As soon as the current is removed, the material reverts to its previous state and the connection – and flow of information – is broken. To address this, the team, which includes researchers from Stanford University, Charles Stark Draper Laboratory, University of Maryland and the MIT, created a 'set and forget' switch capable of maintaining the connection without any additional energy.

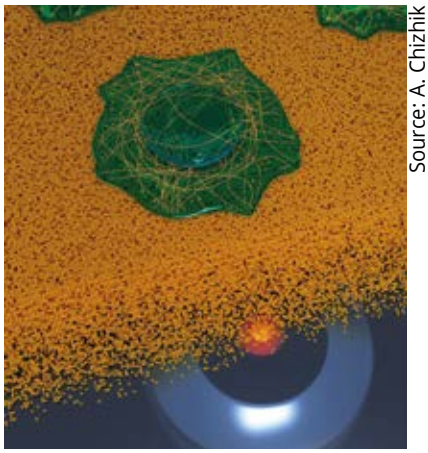
They used a phase-change material that is nonvolatile – it remains in one state until it receives another heat pulse, at which point it reverts back to its original state. This eliminates the need to constantly input energy to maintain the desired state. So they introduced a layer of graphene between an undoped 220 nanometer silicon layer to propagate light and the phase-change material. This design directs all heat generated by the graphene to go towards changing the phase-change material. The switching energy density of this setup is only 8.7 attojoules/nm^3, a 70× reduction compared to the widely used doped silicon heaters, the current state-of-the-art.

Reference: *Z. Fang* et al.: Ultra-low-energy programmable non-volatile silicon photonics based on phase-change materials with graphene heaters, Nat. Nano., online 4 July 2022; DOI: 10.1038/s41565-022-01153-w

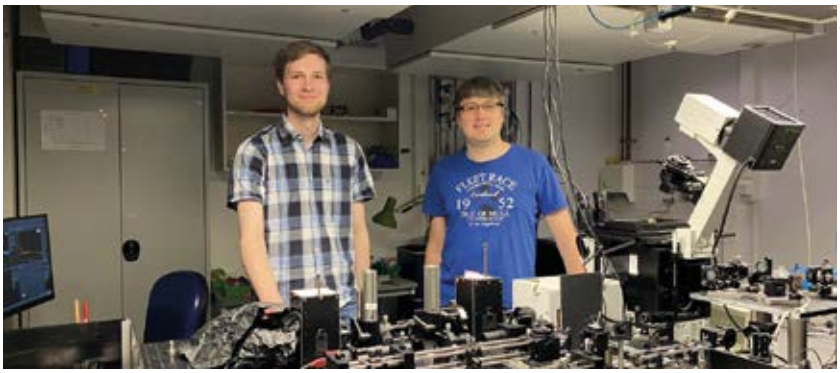
www.ece.uw.edu

Nanometer-scale imaging with 3D super-resolution

New method shows promise to become a powerful tool for multiplexed 3D microscopy



Source: A. Chizhik



Source: O. Nevskyi

Above: Christoph Thiele and Oleksii Nevskyi from the University of Göttingen, Third Institute of Physics – Biophysics. **Left:** Artistic rendering illustrating cells imaging on a gold surface resolving microtubules network and clathrin coated pits

Over the last two decades, microscopy has seen unprecedented advances in speed and resolution. However, cellular structures are essentially three-dimensional, and conventional superresolution techniques often lack the necessary resolution in all three directions to capture details at a nanometer scale. A research team led by Göttingen University, including the University of Würzburg and the Center for Cancer Research in the US, investigated a superresolution imaging technique that involves combining the advantages of two different methods to achieve the same resolution in all three dimensions; this is isotropic resolution.

One of the methods that can achieve a resolution in the nanometer range is metal-induced energy transfer (MIET) imaging. The exceptional depth resolution of MIET imaging was combined with the extraordinary lateral resolution of single-molecule localization microscopy, in particular with direct stochastic optical reconstruction microscopy (dSTORM). The novel technique based on this combination achieves isotropic 3D superresolution imaging of subcellular structures. In addition, the researchers implement dual-color MIET-dSTORM enabling them to image two different cellular structures in 3D, for example microtubules and clathrin coated pits – tiny structures within cells – that exist together in the same area.

Oleksii Nevskyi explains, "This will be a powerful tool with numerous applications to resolve protein complexes and small organelles with sub-nanometer accuracy. Everyone who has access to confocal microscope technology with a fast laser scanner and fluorescence lifetime measurements capabilities should try this technique."

Reference: *J. C. Thiele* et al.: Isotropic three-dimensional dual-color super-resolution microscopy with metal-induced energy transfer, Sci. Adv. **8**, abo2506 (2022); DOI: 10.1126/sciadv.abo2506

www.uni-goettingen.de

First optical 1000BASE-RH SFP module presented

Test houses welcome new small pluggable transceiver module for evaluation of optical Gb ethernet

KDPOF, supplier for gigabit connectivity over fiber optics, has developed and validated the first 1000BASE-RH SFP module for optical gigabit connectivity in vehicles.

The design of the new small form-factor pluggable transceiver module is based on a standard SFP supporting MSA registers via I2C bus. The module can operate at 100 and 1,000 Mb/s. It integrates the whole 1000BASE-RHC PHY and the header connector for SI-POF optical harness. "Our new SFP module was tested and validated in a functional demo recently," stated Carlos Pardo, CEO and co-founder of KDPOF. "We are proud to accomplish the first milestone for future commercial optical 1000BASE-RH SFP modules that will integrate into the automotive optical ecosystem."

Suds Rajagopal, co-founder and vice president of Aukua Systems, a provider of precision Ethernet and IP test and monitoring solutions, welcomes the new SFP from KDPOF: "As a test tool supplier for automotive Ethernet, we have been looking forward to this module. We are happy to integrate the optical 1000BASE-RH interfaces in our test equipment to eveluate KDPOF's optical network design."

The new SFP supports 1000BASE-X, 100BASE-X, and SGMII (with and without auto-negotiation) as electrical interfaces. It monitors the received optical power, the link margin, the junction temperature, and the supply voltages, among others.

The SFP design has been sampled and validated. Presently, KDPOF and Aukua are collaborating to optimize the 1000BASE-RHC SFP and make it available in the third quarter of 2022.

KDPOF has designed the first optical 1000BASE-RH SFP module for automotive Ethernet (Source: KDPOF)

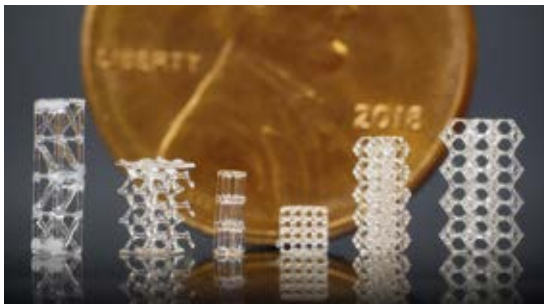
www.kdpof.com
www.aukua.com

Meet KDPOF at its ECOC presentations

3D-printing for glass microstructures

New technology enables faster production, greater optical quality and design flexibility

Researchers at University of California Berkeley have developed a new way to 3D-print glass microstructures that is faster and produces objects with higher optical quality, design flexibility and strength. Working with scientists from the Albert Ludwig University of Freiburg, Germany, the researchers expanded the capabilities of a 3D-printing process they developed three years ago – computed axial lithography (CAL) – to print much finer features and to print in glass. They dubbed this new system 'micro-CAL'.



3D-printed glass lattices, displayed in front of a US penny for scale. (Source: J. Toombs)

Glass is the preferred material for creating complex microscopic objects, including lenses in compact, high-quality cameras used in smartphones and endoscopes, as well as microfluidic devices used to analyze or process minute amounts of liquid. But current manufacturing methods can be slow, expensive and limited in their ability to meet industry's increasing demands. The CAL process is fundamentally different from today's industrial 3D-printing manufacturing processes, which build up objects from thin layers of material.CAL, however, 3D-prints the entire object simultaneously. Researchers use a laser to project patterns of light into a rotating volume of light-sensitive material, building up a 3D light dose that then solidifies in the desired shape. The layer-less nature of the CAL process enables smooth surfaces and complex geometries.

Hayden Taylor, principal investigator and professor of mechanical engineering at UC Berkeley, said: "Now, with micro-CAL, we can print objects in polymers with features down to about 20 millionths of a meter. And for the first time, we have shown how this method can print not only into polymers but also into glass, with features down to about 50 millionths of a meter."

To print the glass, Taylor and his research team collaborated with scientists from the ALU who have developed a special resin material containing nanoparticles of glass surrounded by a light-sensitive binder liquid. Digital light projections from the printer solidify the binder, then the researchers heat the printed object to remove the binder and fuse the particles together into a solid object of pure glass. "The key enabler here is that the binder has a refractive index that is virtually identical to that of the glass, so that light passes through the material with virtually no scattering," said Taylor.

Reference: *J. T. Toombs* et al.: Volumetric additive manufacturing of silica glass with microscale computed axial lithography, Science **376**, 308 (2022); DOI: 10.1126/science.abm6459

https://me.berkeley.edu
www.imtek.uni-freiburg.de

Metalenses generate and focus VUV light

Solid-state nanophotonic technology could potentially replace cabinets of equipment

Rice University researchers have created a metalens that could be very useful for the ultraviolet optics market. By precisely etching hundreds of tiny triangles on the surface of a microscopic film of zinc oxide, nanophotonics pioneer Naomi Halas and colleagues created a metalens that transforms incoming long-wave ultraviolet (UV-A) into a focused output of vacuum ultraviolet (VUV) radiation. VUV is used in semicon manufacturing, photochemistry and materials science and has historically been costly to work with, in part because it is absorbed by almost all types of glass used to make conventional lenses.

Rice University student Catherine Arndt helped create a solid-state metalens that transforms long-wave UV into focused UV radiation. (Source: J. Fitlow, Rice U.)

"This work is particularly promising in light of recent demonstrations that chip manufacturers can scale up the production of metasurfaces with CMOS-compatible processes," said Halas. "This is a fundamental study, but it clearly points to a new strategy for high-throughput manufacturing of compact VUV optical components and devices." Halas' team showed its microscopic metalens could convert 394-nanometer UV into a focused output of 197-nanometer VUV. The disc-shaped metalens is a transparent sheet of zinc oxide that is thinner than a sheet of paper and just 45 millionths of a meter in diameter. In the demonstration, a 394-nanometer UV-A laser was shone onto the back of the disc, and researchers measured the light that emerged from the other side.

In previous work, Halas, Peter Nordlander and others demonstrated they could transform 394-nanometer UV into 197-nanometer VUV with a zinc oxide metasurface. Like the metalens, the metasurface was a transparent film of zinc oxide with a patterned surface. But the required pattern was not as complex since it did not need to focus the light output.

Din Ping Tsai of City University of Hong Kong helped produce the intricate metalens surface. Tests at Rice showed the metalens could focus its 197-nm output onto a spot measuring 1.7 µm in diameter, increasing the power density of the light output by 21×.

Reference: *M. L. Tseng* et al.: Vacuum ultraviolet nonlinear metalens, Sci. Adv. **8**, abn5644 (2022); DOI: 10.1126/sciadv.abn5644

https://halas.rice.edu

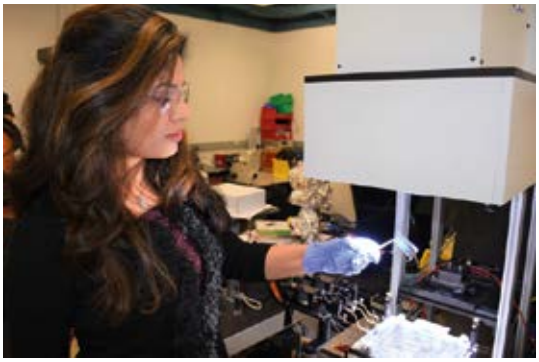
Solar arrays capture more light

Optical concentrator gathers over 90 % of the light from all angles

Many solar arrays actively rotate towards the sun as it moves across the sky to capture as much energy as possible. This makes them more efficient, but also more expensive and complicated to build and maintain. These active systems may not be necessary in the future. At Stanford University, engineering researcher Nina Vaidya, now an assistant professor at the University of Southampton, designed a device that can efficiently gather and concentrate light that falls on it, regardless of its angle or frequency.

The device called AGILE – axially-graded index lens – looks like an upside-down pyramid with the point lopped off. Light enters the square, tileable top at any angle and is funneled down to create a brighter spot at the output. In their prototypes, the researchers were able to capture >90 % of the light and create spots at the output that were three times brighter than the incoming light. Installed in a layer on top of solar cells, they could make solar arrays more efficient and capture not only direct sunlight, but also diffuse light that has been scattered by the Earth's atmosphere, weather, and seasons.

A top layer of AGILE could replace the existing encapsulation that protects solar arrays, create space for cooling and circuitry to run between the narrowing pyramids of the individual devices, and, most importantly, reduce the amount of solar cell area needed to produce energy – and hence reduce the costs. And the uses are not limited to terrestrial solar installations: if applied to solar arrays being sent into space, an AGILE layer could both concentrate light without solar tracking and provide the necessary protection from radiation.



Nina Vaidya measuring the experimental performance of optical concentrators under a solar simulator that acts as an artificial sun. (Source: N. Vaidya)

Reference: *N. Vaidya & O. Solgaard*: Immersion graded index optics: theory, design, and prototypes, Microsyst. Nanoeng. **8**, 69 (2022); DOI: 10.1038/s41378-022-00377-z

https://ee.stanford.edu

PCI Gen 3.0 express frame grabber

BitFlow Cyton-CXP provides dynamic 3D visualization for industrial inspection

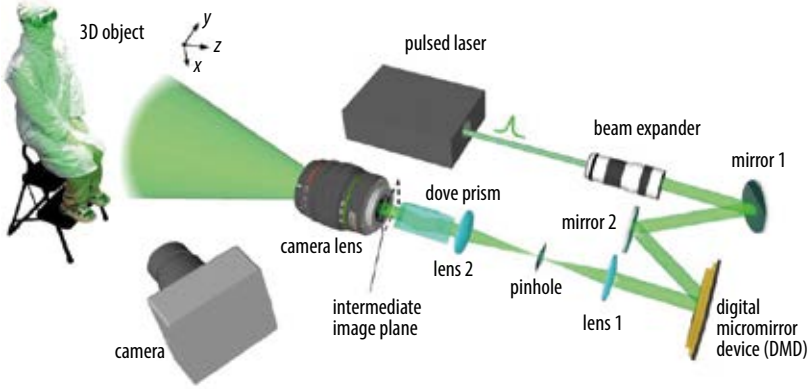
CoaXPress (CXP) is an asymmetric high-speed point-to-point serial communication standard for the transmission of video and still images, scalable over single or multiple coaxial cables. It has a high speed downlink of up to 12.5 Gbps per cable for video, images and data, plus a lower speed uplink up to 42 Mbps for communications and control, and optionally also remote power.

"Applications for CoaXPress are evolving with new use cases being found in precise medical research and 3D inspection where CameraLink or GigE Vision previously were the go-to standard," said Donal Waide, director of sales for BitFlow. "Speed combined with stability, plus a growing choice of compatible cameras, have sparked a great deal of interest for CoaXPress in laboratory settings."

Profilometry is an imaging technique used to extract topographical data from a surface in order to obtain surface morphology, step heights and surface roughness. Dynamic 3D surface imaging by phase-shifting fringe projection profilometry (PSFPP) has been widely implemented in industrial manufacturing, archaeological inspection, entertainment, and biomedicine. Researchers at the INRS Énergie Matériaux Télécommunications Research Centre in Quebec, Canada developed a technique they termed multi-scale band-limited illumination profilometry or MS-BLIP. Supported by the synergy of dual-level intensity projection, multifrequency fringe projection, and an iterative method for distortion compensation, MS-BLIP can accurately discern spatially separated 3D objects with highly varying reflectance.

The deformed structure images are captured by an Optronis CP70-1HS-M-1900 CoaXPress camera with an Azure lens. The acquired images are transferred to a computer via a cable to a BitFlow Cyton-CXP frame grabber built on a half-size x8 PCI Gen 3.0 express board compliant with the CXP 1.1 standard. MS-BLIP has proved successful in the dynamic 3D visualization of translational movements of an engineered box, and full human body movements at a measurement volume three times greater than existing BLIP systems.

www.bitflow.com



Above: BitFlow Cyton CXP CoaXPress frame grabber
Left: Schematic of the MS-BLIP system
(Sources: BitFlow)

EPIC events encompass photonics

Join this fall at the University of Glasgow to discuss quantum photonics, at Imec's Leuven site for CMOS-compatible integrated photonics and at ESA's Noordwijk facility for New Space.

EPIC aims to contribute to the photonics revolution, especially in Europe, where both challenges and opportunities are rapidly increasing. EPIC initiatives, such as the technology meetings, are committed to promoting its members and to creating special occasions to nurture business collaboration among the photonics community and with end-users all over the world. On May 2022, we were very happy to finally celebrate the EPIC Meeting on Advanced Micro-Optics: Simulation, Fabrication and Characterization at Nanoscribe, which had had to be postponed due to the first pandemic outbreak. More than fifty attendees came to the facilities in Karlsruhe, Germany, for the two-day conference and networking event where we had the chance to listen to several presentations on advanced manufacturing of micro-optics and use cases in different application fields such as sensors, automotive lighting, augmented reality, virtual reality, data communications, or consumer electronics.

In the early summer, EPIC also organized several technology meetings and networking sessions at leading photonics industry events, like the RoundTable at Optro 2022 on "Smart Optronic Detectors for Challenging Targets". The discussion took place in Versailles, France, and focused on the prospects for the European defense industry and the technological challenges in present and future applications such as ghost imaging, hyper and multispectral systems, or 3D lidar. In the domain of lasers, we gathered experts in beam shaping for industrial applications at Lasys in Stuttgart.

Family picture of the EPIC Meeting held at Nanoscribe in May 2022 (Source: Nanoscribe)

Images from different EPIC Technology Meetings (Source: EPIC)

Germany was also the location for other networking events hosted by EPIC, like the VIP Breakfast and the TechWatch at W3+Fair 2022 in Wetzlar, and the pitch session at the Aachen Polymer Optics Days in Aachen.

We have started the third quarter of the year with our batteries fully charged to discuss three hot topics where Europe is working hard: Quantum, Integrated Photonics and New Space. On 7 – 8 of September, the EPIC team will split to host two simultaneous events: the EPIC Industrial Quantum Photonics Technology Summit at the University of Glasgow, UK, and the EPIC Meeting on CMOS-Compatible Integrated Photonics at Imec's headquarters in Leuven, Belgium (cf. p. 67). And a few days later, on 13 – 14 of September, our team will travel to the European Space Agency facilities in Noordwijk, The Netherlands, where we will hold the EPIC Meeting in Photonics at the Final Frontier.

Besides boosting collaboration among the attendees during the technological meetings, we also provide our members with strategic insights about photonics markets. Here are some reports that have been published recently: EPIC Market Report – Precision Micromachining by Johannes Trbola; EPIC's Special Report on Interband and Quantum Cascade Lasers by Tematys, 2021; EPIC's Special Report on Silicon Photonics by Yole Developpement, 2021; EPIC's Special Report on Lidar by Yole Developpement, 2021. Every employee of any company member of EPIC has free access to the EPIC library on the Extranet.

www.epic-assoc.com

Upcoming EPIC events:

- 7 – 8 September 2022
  EPIC Industrial Quantum Photonics Technology Summit at the University of Glasgow, UK
- 7 – 8 September 2022
  EPIC Meeting on CMOS Compatible Integrated Photonics at imec, Leuven, Belgium (cf. p. 67)
- 8 September 2022
  EPIC TechWatch at CIOE on Precision Optics, Shenzhen, China
- 12 September 2022, 15 – 17 CEST
  EPIC Online Technology Meeting on Emerging Trends in Laser Micromachining
- 13 – 14 September 2022
  EPIC Meeting on Photonics at the Final Frontier at European Space Agency, Noordwijk, Netherlands
- 19 September 2022
  EPIC VIP Networking Reception at ECOC, Basel, Switzerland
- 21 September 2022
  EPIC Members Run at ECOC, Basel, Switzerland
- 21 September 2022
  EPIC TechWatch at ECOC, Basel, Switzerland
- 26 September 2022, 15 – 17 CEST
  EPIC Online Technology Meeting on Photonics for Aesthetics and Cosmetics
- 5 October 2022
  EPIC Meeting on New Machine Vision Developments and Emerging Applications at Vision fair, Stuttgart, Germany
- 17 October 2022, 15 – 17 CEST
  EPIC Online Technology Meeting on Lasers for Mobility of the Future
- 21 October 2022
  Day of Photonics

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DGaO Deutsche Gesellschaft für angewandte Optik
The German Branch of the European Optical Society

TECHNISCHE UNIVERSITÄT BERLIN

INVITATION AND PROGRAM CALL

The German Society for Applied Optics (DGaO) invites you to the

124TH ANNUAL MEETING OF THE DGaO

30 May – 3 June 2023 in Berlin, Germany
at the Technical University Berlin

The following main topics from applied optics will be in focus:

- Optical metrology and measuring systems
- Optics design
- Laser optical applications
- Optical communications engineering
- Synchrotron and x-ray optical applications
- Quantum optics and micro-optics
- Light and illumination engineering
- Optical components and systems

Source: Philipp Arnoldt Photography

Call for abstracts

We invite you to submit oral presentations (12 min plus 3 min discussion) and posters from the list of topics above or from the general field of applied optics. Please use the online system at www.dgao.de. The abstracts should not exceed 1200 characters (including blank characters).
Conference language is German, English contributions are welcome.

Program Committee

Prof Dr Christian Faber, Hochschule Landshut; Prof Dr Dirk Oberschmidt, IWF TU Berlin; Dr Alexander Bielke, ASML Berlin; Dr Robert Brüning, Fraunhofer IOF Jena; Prof Dr Jürgen Czarske, TU Dresden; Dr Adrian Grewe, Carl Zeiss AG Jena; Marco Hanft, Carl Zeiss AG Jena; Dr Meike Hofmann, TU Ilmenau; Christof Pruß, ITO Universität Stuttgart; Dr Henning Rehn, Fisba AG St. Gallen; Christian Schober, ITO Universität Stuttgart; Dr Rainer Schuhmann, formerly Berliner Glas; Dr Christian Sinn, Köln Optik; Dr Andrea Toulouse, ITO Universität Stuttgart; Dr Florian Willomitzer, Wyant College of Optical Sciences, University of Arizona

DGaO Young Scientists Award

In 2023, the DGaO will again award the DGaO Young Scientists Award for the best dissertation and for the best master's thesis of 2022 in the field of applied optics. Detailed information is available on the DGaO website. Proposals for the DGaO Young Scientists Award can be submitted until January 31, 2023, to the DGaO office (katja.richter@dgao.de).

Deadlines

Submission of abstracts: until January 13, 2023 (receipt)
Notification of acceptance: February 24, 2023
Program mailing and publication: April 14, 2023
Binding registration: from the beginning of March 2023
End early-bird registration: until April 28, 2023

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Lively discussions at the 123rd DGaO Annual Meeting at Pforzheim University

After the restrictions of the last two years, the 123rd Annual Meeting of the German Society for Applied Optics took place completely in presence from June 7 – 11. The organization and realization of the conference was in the hands of conference managing director Prof Steffen Reichel and team, who provided the ideal environment at Pforzheim University. A total of about 180 participants from Germany, Switzerland, Austria, the Czech Republic, France and the Netherlands accepted the invitation. From about 100 submissions, the program committee put together a varied program of 6 keynote lectures, 14 lecture sessions, a poster exhibition and a special symposium on Photonic Technologies for Quantum Applications. The main topics this year were metrology, light sources, displays, image processing and machine learning, optical design and photonic technologies. A welcome aspect of the conference was the lively discussion in the hallways between sessions. Attendees made extensive use of the long-missed opportunity to engage in more in-depth technical discussions, and either providing or receiving new impetus.

Source all images: DGaO

The participants of this year's DGaO conference in front of the Audimax building of Pforzheim University.

The conference was opened on Tuesday with a welcome event at which Tanja Solombrino, a research associate at the university and city guide of the city of Pforzheim, led the guests through the history of the jewelry and gold city of Pforzheim. The city on the Enz river has a long tradition in craftsmanship and artistic design. This background motivated the founding of the university in 1877 to provide training in the skills needed for the growing jewelry and watchmaking industry.

On Wednesday the professional conference program began after a welcoming address by Prof Ulrich Jautz, the university's rector. Prof Steffen Reichel then presented the research focus of the faculty for technical optics. With work on display technology, image processing and optical metrology, technology is being developed here for the mobility of tomorrow. The following sessions focused on optical design, additive manufacturing and machine learning. The poster session took place in the late afternoon and again there were lively discussions at the various stations.

The technical focus on Thursday morning was on topics of optical design and simulation. This year there were several contributions from the field of microscopy. An overview of different designs was presented and issues of correction and use of color errors were discussed. Research results were also presented that show how optics development can benefit from artificial intelligence technology. The afternoon was specifically reserved for maintaining existing as well as establishing new networks and contacts. Conference participants took buses to the nearby town of Bretten where the picturesque town center has many historic buildings around the market square. There was an opportunity during the guided tour of the town to learn more about Philipp Melanchthon as the son of the town and a companion of Martin Luther. Impressions of the visit to Bretten or impulses from the lectures could be deepened in a convivial atmosphere during dinner at the university.

The symposium on Friday morning was entitled "Photonic Technologies for Quantum Applications". The three lectures: "From photons to quantum computers – the role of light in quantum technology" (Prof Dieter Meschede, University of Bonn), "Nano meets Quantum – Nanophotonics for new regimes in quantum optical precision experiments" (Prof Stefanie Kroker, Technische Universität Braunschweig) as well as "Perspectives of quantum imaging – from fundamentals towards biomedical application" (Dr Markus Gräfe, Fraunhofer IOF Jena) provided insights into the complexity and current state of research in quantum technology.

The DGaO Young Investigator Awards were presented in the afternoon. The prize for the best doctoral thesis went to Andrea Toulouse (University of Stuttgart) for her work on "Complex 3D-printed micro-optical systems". The prize for the best master's thesis was awarded to Dennis Pohle (Dresden University of Technology) for his work on "Surveillance of Multimode Fiber Networks using Deep Learning". Both introduced the auditorium to details of their work with accompanying presentations.

At the subsequent general meeting, Prof Dirk Oberschmidt from the Technical University of Berlin was appointed as conference managing director 2023. The DGaO will then return to its founding location of Berlin on its 100th anniversary for its annual conference.

The thematic conclusion on Friday was the Fraunhofer lecture by Prof Michael Totzeck (Carl Zeiss AG) on the topic of "Optical Lithography for the Production of Microchips". This lecture developed into a real technology thriller with the excitingly prepared review of the difficulties with 157 nm technology. For example, a way of dealing with unexpected higher order birefringence in CaF_2 had to be found. The auditorium followed Prof Totzeck's explanations of the ups and downs in the development

Presentation of the DGaO Young Investigator Awards for the best dissertation 2021 to Dr Andrea Toulouse (left, center) and master's thesis 2021 to Dipl-Ing Dennis Pohle (right, center) by Prof Heinrich and Ms Kafka, respectively.

of optical lithography with rapt attention. At the Fraunhofer Gala Dinner, the poster prize was awarded to Jan Krüger from PTB for the paper entitled "Investigation of the influence of vibration on measured point spread functions in optical microscopy".

Saturday also held some highlights: Michael Thiel (Nanoscribe) guided the expert audience through the latest developments in multiphoton lithography, for example. Rohan Kundu (Fraunhofer IOF) presented a micro-optical lightfield display – including a live demonstration in front of the impressed audience. Subsequently, topics of system tolerances and nanophotonics were presented in two further sessions and simultaneously formed the conclusion.

This year's annual meeting was a very great success. The framework created was perfect, and the challenging technical program was interesting and stimulating. The visitors made extensive use of the opportunities for direct professional and personal exchange and enjoyed them. Interesting developments in software, components and technologies could be seen at the industrial exhibition, such as phosphor ceramics or an optical computing software – both products are "Made in Germany". We would like to take this opportunity to thank all the sponsors once again, and special thanks go to Prof Steffen Reichel and the entire team at Pforzheim University. At the 123rd annual meeting of the DGaO, the broad scientific/technical exchange of experts in applied optics was very successful after two difficult years of the pandemic.

www.dgao.de

AKL eV has a new management team

General meeting elects new board

Dr Markus Kogel-Hollacher from Precitec and Dr Claus Schnitzler from Amphos were elected as the association's new managing director and treasurer on May 5. The four-member executive board consists of chairman Ulrich Berners, deputy chairman Constantin Häfner, managing director Markus Kogel-Hollacher and treasurer Claus Schnitzler.

AKL eV was founded in 1990 to make the fascinating possibilities opened up by the laser as a tool in terms of precision, speed, and economy, available for industrial use by intensifying the level of information and training. Today, many of the lasers' application possibilities are known and the processes have been tested. Nevertheless, new laser beam sources and laser processes are constantly being developed, leading to innovative perspectives in industrial manufacturing. In this rapidly changing discipline, AKL eV with its network of more than 180 members serves to effectively promote and support innovation processes.

Dr Kogel-Hollacher began his work in the field of lasers at the Fraunhofer Institute for Laser Technology. Since then, his work has focused on the monitoring and control of laser processes. In 1996, he moved to Precitec. Dr Kogel-Hollacher is a fellow of the Laser Institute of America, a member of the board of stakeholders at Photonics21 in Brussels, and was a finalist for the Innovation Award Laser Technology in 2012 and 2014.

Dr Schnitzler studied physics at RWTH Aachen University and developed 'InnoSlab' lasers with medium to high power from 1999 to 2003. Together with the InnoSlab project group, he won 2nd place at the Berthold Leibinger innovation awards for this work. He is co-founder and has been managing director of Amphos GmbH since 2010, one of the most successful spin-offs from the Fraunhofer ILT and a leader in the field of high-power ultrashort-pulse lasers, part of the Trumpf group since 2018.

"I would like to thank the assembly for the unanimous election result and the trust placed in me for the office of managing director of AKL eV," said Dr Kogel-Hollacher as he accepted the election.

Source: Fh. ILT / AKL eV

Dr Markus Kogel-Hollacher (l.) Dr Claus Schnitzler

Professor Constantin Häfner, director of Fraunhofer ILT, added at the general meeting: "We are very pleased that we can further expand our network with the newly elected member of the board of AKL eV. On behalf of all members, I would like to thank Dr Hartmut Frerichs and Dr Bernd Schmidt, who are leaving the board, for their commitment, work and support."

www.akl-ev.de

Microtechnology sector focuses on sustainability

Challenges due to the Corona pandemic mastered well

The IVAM Microtechnology Network presents its Economic Survey for 2022: innovations in the industry provide solutions to the energy and climate crisis.

The microtechnology industry has managed the Corona crisis quite well and is currently focusing intensively on sustainability. The industry is concerned about the impending shortage of skilled workers and about political developments. The results of the industry survey conducted by the IVAM Microtechnology Network in spring 2022 reflect macroeconomic challenges.

The topic of sustainability has arrived at the majority of the companies surveyed – a total of 78.3 % operate sustainably to a greater or lesser extent. So far, 10.9 % of respondents are operating completely sustainably. In some areas, 41.3 % are sustainable and a sustainability concept is currently being developed at 26.1 % of the companies. Only 6.5 % state that they do not work sustainably and also have no concept in planning.

The survey has also asked about the microtechnology industry's specific contribution to promoting sustainability in Germany and Europe. This takes the form of products and/or technologies that, for example, helps to save resources, help to avoid climate damaging waste products or produces reusable materials.

30 % of the companies and 23.1 % of the research institutes state that their products are relevant to a sustainable or circular economy. In terms of technology, the relevance of the industry is even clearer – 76.9 % of institutes and 39.4 % of companies are developing technology that helps promote sustainability.

60 % of companies report that their sales have increased in 2021 to the previous year. For 20 %, sales have remained stable. A similar trend can be seen in employee numbers. At 50 % of the companies surveyed, there was an increase in employee numbers in 2021. At 36.7 %, the figure remained unchanged. Only exports grew to just a moderate extent. 23.3 % of the companies stated that their exports had increased, while exports remained stable for 30.2 % of companies. This could be an indication that production is increasingly shifting to the national market.

In terms of forecasts, the mood at the time of the survey in February 2022 was also optimistic. The majority of respondents expect both sales and employee numbers to increase over the next three years (60 % and 83.3 % respectively). A renewed increase in exports was seen by 41.9 % of companies in February. It remains to be seen whether this development will actually continue after the outbreak of the war in Ukraine.

In the last survey in 2020, the industry was already strongly confronted with the challenge of finding and retaining suitable skilled workers. The proportion of organizations that see this as an internal uncertainty factor has risen even further since then. For 70 % of companies and 84.6 % of research institutions surveyed, the issue of attracting and retaining skilled workers is the biggest uncertainty factor in terms of internal development opportunities.

www.ivam.de

VDMA bundles competences – focus on quantum technologies

Vision of bundling the existing competences and resources

By working together in one joint forum, synergies within the association are utilized and invested in commitment to the future of quantum technology and photonics.

In the coming years, quantum technology will also enable considerable leaps in innovation in mechanical and plant engineering, as it will make it possible, among other things, to introduce completely new measuring methods or to place materials research on a new footing. The VDMA has been accompanying this change for some time now with its Photonics Forum and the activities of several divisions and regional subsidiaries. In order to bundle and network these competences and resources on a single platform and to give the topic of quantum technology better visibility, the Photonics Forum has now been renamed the VDMA Quantum Technologies and Photonics Forum. This was announced to the members at the Future Business Summit at Cern in Geneva in June.

In future, the following VDMA organizational units will work together on the topic of quantum technologies in the forum:

- Competence Center Future Business
- Electronics, Micro and New Energy Production Technologies
- Compressors, Compressed Air and Vacuum Technology
- Laser and Laser Systems for Material Processing
- Regional Subsidiary Baden-Wurttemberg / Alliance Industry 4.0 Baden-Württemberg
- Measuring and testing technology

In the field of photonics, the forum relies on a membership of more than 500 companies and research institutions along the entire value chain – of which about 400 members are mainly active in the field of photonics.

A steering committee on quantum technologies consisting of representatives of the member companies will be established to define the goals of the forum. The activities of the various organizational units of the VDMA will be coordinated by the forum.

The forum uses synergies to anchor quantum technologies and photonics more firmly in the consciousness of politics and the public. Among other things, it uses its own newsletter and the information channel at Industry-Arena for this purpose. In addition, the forum will represent the topics of quantum technologies and photonics at various national and international trade fairs and conferences.

www.vdma.org

New board of directors at VDMA lasers group

The new CEO of the group is Dr Christian Schmitz

At the spring meeting of the VDMA Working Group on Lasers and Laser Systems for Material Processing (AG Laser), the members elected a new board for the next four years.

The new CEO of the AG is Dr Christian Schmitz, Trumpf board member and chairman of its laser technology division. His deputy was Dr Christoph Ullmann, managing director of Laserline. The newly elected board consists of:

- Nicholas Meyer, head of sales and application, EMAG LaserTec
- Dr Stephen Ruppik, managing director of Coherent Rofin-Sinar Laser
- Dr Christian Schmitz, member of the board of directors and chairman of the Trumpf laser technology division
- Dr Christoph Ullman, managing director of Laserline

In addition, a new statute was adopted by the members, which enables suppliers of components directly related to the end application, laser manufacturers and system integrators as well as research institutes and universities to become members of the working group.

There is also a change within the VDMA office: after a vacancy, Dr Sven Breitung takes over the management of AG Laser. Dr Breitung has been with the VDMA since 2009, where he was initially responsible for research, trade fairs and OPC UA in the area of organic and printed electronics and later in the Printing and Paper Technology Association.

www.vdma.org/laser-lasersysteme

Source: VDMA

From left to right: Management and board of directors of the Working Group on Lasers and Laser Systems for Material Processing: Dr Sven Breitung, VDMA; Dr Christian Schmitz, Trumpf Lasertechnik (Chairman); Dr Christoph Ullmann, Laserline (Vice Chairman); Dr Markus Klein as representative for Dr. Stefan Ruppik, Coherent. Nikolas Meyer, EMAG LaserTec, is missing. Image source: VDMA

Laser industry 2022: development and challenges

VDMA presents survey results at Lasys press conference

Sven Breitung, managing director of the working group lasers and laser systems for material processing gave an overview of the market situation of the laser industry from the point of view of the members participating in the survey. These include on the one hand the leading manufacturing companies of laser beam sources and laser processing systems and on the other hand producers of optical components as well as other equipment for laser technology.

84 % of the members who participated in the survey stated that the order intake of 2021 had increased compared to 2020. Values of 6 – 20 % were predominantly cited regarding the level of increase in order intake from 2021 compared to 2020.

The development of incoming orders abroad from 2021 compared to 2020 was even more positive. 94 % of the members stated that this had increased by 11 – 20 % or even more.

Also asked in the survey was the development of sales from 2021 compared to 2020 and the companies participating in the survey indicated that sales had increased for 82 % of the companies and 18 % of the companies indicated a decrease.

The amount of the increase varied widely, according to the companies participating in the survey. 15 % indicated that sales increased by 0 – 5 % and 46 % indicated that the increase was between 6 and 15 %. 15 % indicated that the increase was 16 – 20 % and 23 % even indicated an increase of over 20 %.

Expectations for 2022 versus 2021 for domestic and international order intake also showed a positive trend, with 88 % of the companies participating in the survey expecting an increase and only 12 % expecting a decrease.

The majority of companies (54 %) expect an increase in incoming orders from Germany of between 6 and 15 %. Members are even more optimistic about incoming orders from abroad: half of them expect an increase in incoming orders from abroad of more than 16 %.

When it comes to expectations for sales, members of the working group are unanimous: all companies expect an increase compared to 2021. More than two thirds of the companies expect double-digit increases in sales.

The markets supporting the expected strong increase in order intake were identified in the USA, Germany, Asia and there especially China. Also named were various application markets such as medical, mobility, and consumer and household electronics, which support the increase in order intake. Regions such as China, Europe and Russia were cited as particularly difficult markets but also the commoditization of lasers and supply chain issues.

The problems in the supply chain and in particular the supply of electronic components will not be solved until 2023 or later, according to two-thirds of the members. One-third is more optimistic and expects relief in the supply of electronic components as early as the second half of 2022.

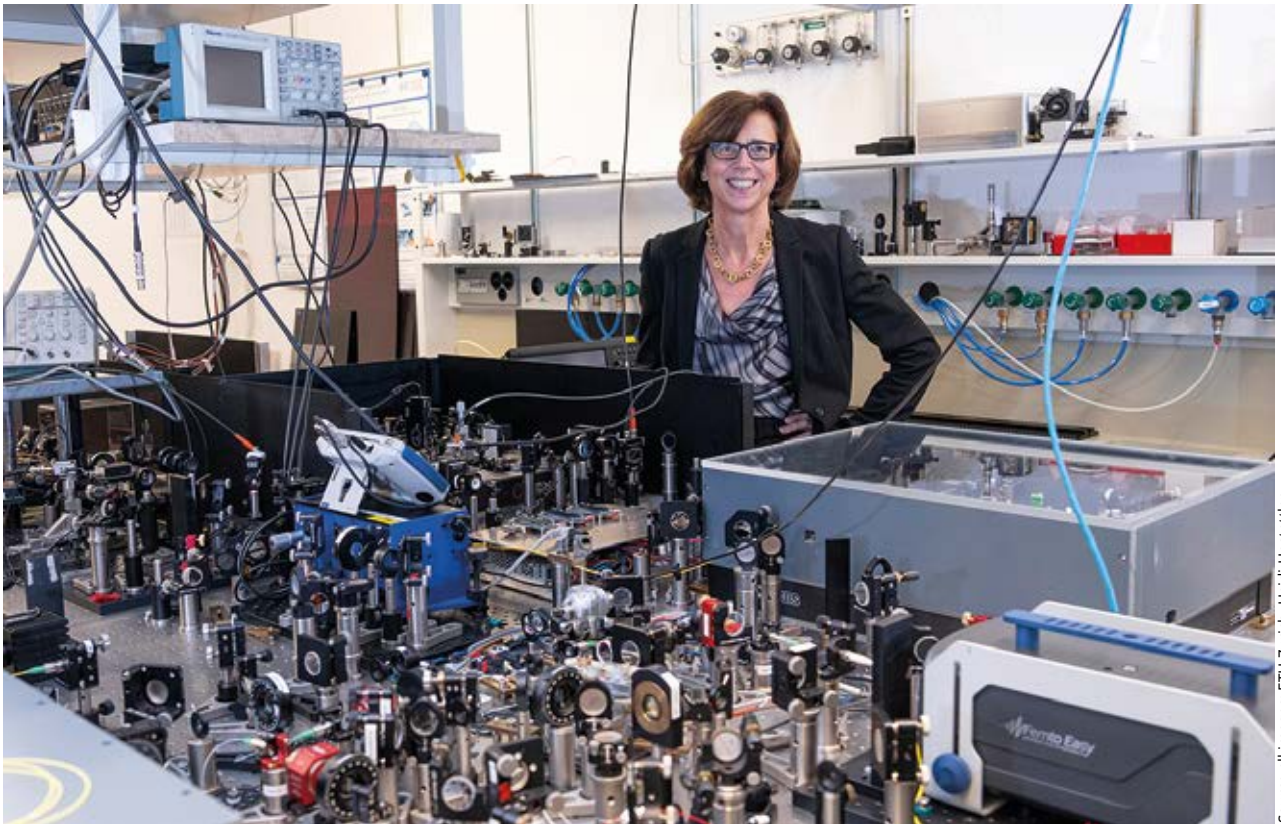
www.vdma.org/laser-lasersysteme

Source: Wiley

Panel at Lasys (l. to r.): Dr Christoph Ullmann (Laserline), Ralf Kimmel (Trumpf), Dr Sven Breitung (VDMA), Roland Bleinroth (Messe Stuttgart), Nikolas Meyer (EMAG LaserTec), Gunnar Mey (Messe Stuttgart)

"Open the door to something better"

Prof Ursula Keller on the challenges of being a woman in STEM – in Europe and abroad



Source all images: ETH Zurich, Heidi Hostettler

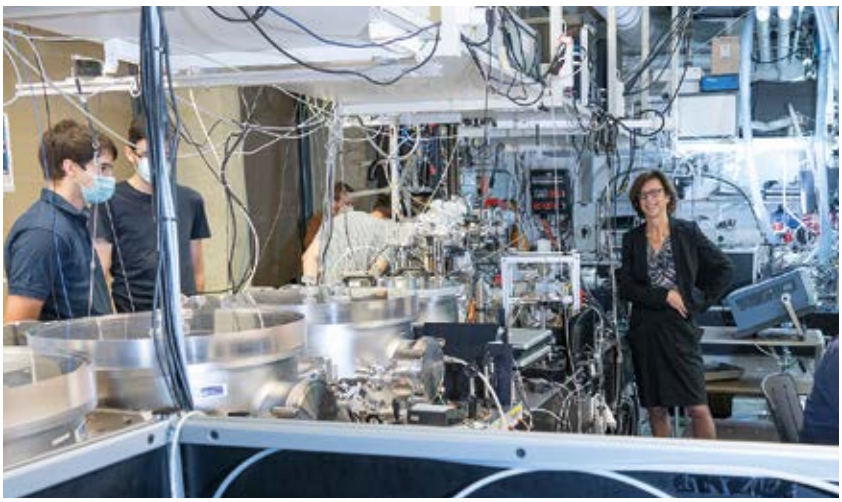
The first tenured woman physics professor at ETH Zurich, and a career-long campaigner for fair play and a level playing field for women in science, Ursula Keller, talks to Francesca Moglia, EPIC's former photonics technologies program manager.

What is the background to your appointment as professor of physics at the ETH?

Coming from a working-class background, I was the first ever in my family to go to university. In 1984, I graduated top of my class with an MSc in physics from the Swiss Federal Institute of Technology (ETH) in Zürich. I then began a PhD in applied physics at Stanford University in the US where I worked on a novel high-speed optical measurement technique of charge and voltage in GaAs integrated circuits and low-noise ultrafast laser systems. After my PhD, I joined AT&T Bell Labs at Holmdel, New Jersey, as a member of the technical staff and began my independent research career right after my PhD, exploring and pushing the frontiers in ultrafast science and technology in relation to photonic switching, ultrafast laser systems, and semiconductor spectroscopy. In 1991, after a national demonstration by Swiss women, the ETH, which at the time was almost entirely male dominated, came under political pressure to hire more women, and in 1993 I was one of the first ten 'quota women' to be hired as a tenured Professor. In 1997 I became a full professor and in 2010 I was appointed director of the Swiss National Science Foundation's MUST program, i.e. National Center of Competence in Research (NCCR) Molecular Ultrafast Science and Technology – a 45 million euro interdisciplinary research program on ultrafast science in the fields of physics and chemistry [1].

How and why do you think Bell Labs was better at recognizing merits than ETH?

While I was at Stanford doing my PhD, we had regular one-to-one meetings with recruiters from IBM and Bell Labs. In general, since they knew I had the necessary academic and technical ability by being at Stanford, they were more interested in getting a feeling for my personality to determine if I would be a good fit for the company. I chose Bell Labs because they had a long tra-



Ursula Keller and some of her PhD students in the attoline laboratory at ETH

dition of ultrafast and because I would have the complete freedom to run my own lab. This simply would not have been possible at ETH because until 1993 there were no women leading physics research.

What support systems were there at Stanford for women students?

At that time, women physics and engineering PhD students were still a rarity. At Stanford I could benefit from a peer mentoring program which I found very helpful, and which motivated me to establish something similar in the physics department at ETH Zurich with the help of the NCCR MUST outreach officer Dr Anna Garry [2]. At Stanford we shared offices with other students from different groups, and were able to talk to each other and get help and advice. My professor expected me to manage myself. If I needed help, I could ask the senior students or senior postdocs or go directly to my professor, so help was available from both the top and from the bottom. Some students were more independent than others, but everybody could choose who to approach and how to proceed.

What support did you get from women in leadership positions at Stanford?

I was lucky to be taken on by a visiting professor, Geraldine Kenney Wallace, to undertake a theoretical directed study, and of course I got to know her. At Stanford, we had a rotation system where students were encouraged to join different groups, and once she understood that I didn't want a micromanager and what was important to me, she convinced me to go into Dave Bloom's group – even doing a pitch for the professor to take me on. She heavily influenced my choices back then and my future, but they were the right things to be done.

How did you apply your experience at Stanford to your approach for supervising students at the ETH?

I saw my time as a PhD student as a process of growing up – taking charge of my career and learning how to manage myself and when and how to ask for help. From this, I have two guiding principles: flexibility and never to micromanage. All of my students have a particular project when they start, get a copy of the proposal and I always say, if you have a better idea, let me know. I have had graduate students who redefined their PhD because there was a surprise along the way, and I give this flexibility because I don't believe in micromanagement. Someone was able to solve problems and make a success where others had more difficulties and needed more help while someone else joined the group with already clear goals for their careers and I supported them in the best way they required. Not every professor is a perfect fit for every student. In my case, I am always happy to meet students when they encounter a problem or want to discuss their results, but I don't normally have regular fixed meetings, as I think it is best to meet only when there is a need to resolve a particular issue. When we do meet, I expect the student to have a short summary or something else written up. The preparation of the meeting with me usually helps the student a lot to have a better overview of the experiment and the things that have been done, and sometimes the solution or a new idea to overcome the challenge comes up exactly during this process.

Of course, I don't always have the perfect solution and I sometimes tell the student to talk to other students, postdocs and even external collaborators. It can be frustrating when something doesn't work out, but I think that is part of the learning process because you need to learn to develop some frustration tolerance.

How can we get more women into STEM and keep them there?

I would say we need more STEM people, both men and women. Of course, women are still disadvantaged by gender

Organization

EPIC – European Photonics Industry Consortium

EPIC is the world-leading photonics industry association representing more than 780 members across 35 countries. EPIC promotes the sustainable development of organizations working in the field of photonics, EPIC fosters a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement. EPIC publishes market and technology reports, organizes technical workshops and B2B roundtables, supports EU funding proposals, advocacy and lobbying, education and training activities, standards and roadmaps, pavilions at exhibitions.

www.epic-assoc.com

Ursula Keller won the European Inventor Award in Lifetime Achievements in 2018, organized by the European Patent Office.

stereotyping and young girls and women need to be encouraged by having more female role models who are using physics to solve problems in areas that get a broader group of people excited. I personally believe that lasers and photonics in general are very attractive for many interdisciplinary applications in energy, climate change, health, and biology for example.

Then, of course, we have to make sure that those who are actually interested in doing well in STEM don't leave because they are not treated well, for example due to an unsupportive work environment and an informal power structure with limited access to resources and decision making. We also need to better implement support for family and work-life balance issues. It can be done, but it is not business as usual and we need extra support during the baby phase, such as, for example, no teaching for one year after the birth and an additional PhD student to support a postdoc mother, a new program successfully implemented in the physics department at ETH Zurich to keep postdocs employed 100 % with more work-time flexibility and keep them working on a hot topic [3]. This is a great success because studies have shown that pregnant postdocs were very often encouraged to go part-time, take a break or were not even hired. Now you can argue that one pregnant postdoc plus one PhD student is more than one postdoc. This is a win-win situation for all.

How important is it for women to network with other women?

I think it is important for women to network with both women and men. But there is a special need to talk to women when the numbers are well below thirty percent. From my experience as a student, I learned not to mention my weaknesses to my male colleagues. They seldom talked about their own weaknesses and when I mentioned mine, being scared of exams for example, it just fulfilled their female stereotypical bias, and it was used against me. So I learned very early on to keep any fears or doubts to myself.

For this reason, I was always happy when I saw another woman somewhere. In fact, when I arrived at Bell Labs, they had just started organizing formal women-only lunch research sessions once a month after a woman had won a big sexual harassment case. Having had to pay a large financial settlement, the company implemented additional measures whereby all the women scientists and members of technical staff were assigned a personal mentor. Both programs were very helpful for me.

How should the need for women quotas be presented to men who feel victims of reverse discrimination?

Some men are not comfortable with women, especially after the spreading of the 'me, too' movement. For this reason, some of my male colleagues have told me they don't like having a meeting with a woman alone in their room, and if they do, they always keep the door open. A consequence of this is that where men have the choice, they will hire someone who looks like them. That is why women quotas are important. In the physics department at ETH after hiring two 'quota women' professors in 1993, every professor selection committee for the following 22 years resulted in selecting a man with a ratio of 24:0. Only after a crisis with having a woman professor fired, five female tenure-track professors were recruited, within only two years from 2018 to 2020. By 2019 ETH Zurich still had only 14 percent tenured women professors with 32 percent incoming female students [4].

So I have a little bit of a problem when men tell me they feel they are being discriminated against because they don't have any chance to become a professor as only women are being hired. Based on the data, this is simply not true. Men still dominate science and attempts to level up the playing field for women to give them greater equality should not be seen as reverse discrimination. In any event, I think that questioning the status quo is good because it can open the door to something better. We need mandatory education on these issues for both men and women.

Why are transparency and accountability key for good governance?

While women quotas and grants specifically for women are a step in the right direction, they don't address the root causes of the problem. In my view, these are the lack of effective control systems, and the need for greater transparency and accountability in resource allocation and decision making. These more open systems need to replace the current culture of informal, mostly male-dominated power networks with inherent gender and ethnic biases, limited accountability and transparency of decision making.

Unfortunately, the culture of gender bias affects women as well as men. For

example, some women say they would never want to have a woman boss because they are too bossy. This, of course, comes from gender stereotyping in that while it is okay for a male boss to be demanding and questioning or critical of performance, when a woman behaves in the same way she is considered harsh and domineering. In actual fact, it's been proven that women managers spend more time supporting, counselling, and advocating women than men do. A lot of young women need to be aware that they have the same gender bias as men, and they need to guard against being used as a weapon against senior women and women leadership.

Transparency and accountability are also necessary to counter bias in allocating resources to competing sciences. Traditionally, particle physics has always received more money with the argument that it's 'big science' and it has been a struggle to get other areas, such laser science and solid-state, to be recognized as being also more expensive.

If you started again, what would you do differently?

Given where I came from, I have achieved more than I ever dreamed of. I am happily married, I have two great kids and I don't have any major regrets. It has not always been easy, but I think the struggles I have had made me a stronger and better person.

Of course, I have made my share of mistakes, but on the big calls such as going into physics, becoming a professor and starting a family, I made the right decisions. It is important to remember that I only got the chance to become a tenured professor because of all the efforts of many pioneering women before me.

At this point in my career I want to help to leave ETH better than I found it. Through my NCCR MUST directorship I got a direct mandate and resources from the Swiss National Science Foundation to do something for the advancement of women for the last twelve years. We have achieved a lot getting women networked and implementing some real change. I hope that the increasing number of women can support each other for a measurable culture change in the future.

[1] A detailed description of Ursula Keller's career and commitment for a more gender-equal academia at any hierarchy level can be found here: https://ulp.ethz.ch/news/ulp-news/2022/01/what-makes-me-tick-why-do-i-still-want-change-for-more-women-in-stem.html

[2] https://learningteaching.ethz.ch/ Especially the article "Improving the learning environment in the Department of Physics: a peer mentoring program for first-year female physicists alongside changes in the lecture program"

[3] http://www.nccr-must.ch/equal_opportunities/opn_column_reflections_in_diversity/opn_column_december_2016.html

[4] ETH gender statistics, https://ethz.ch/services/en/employment-and-work/working-environment/diversity/strategy-and-numbers.html

Author

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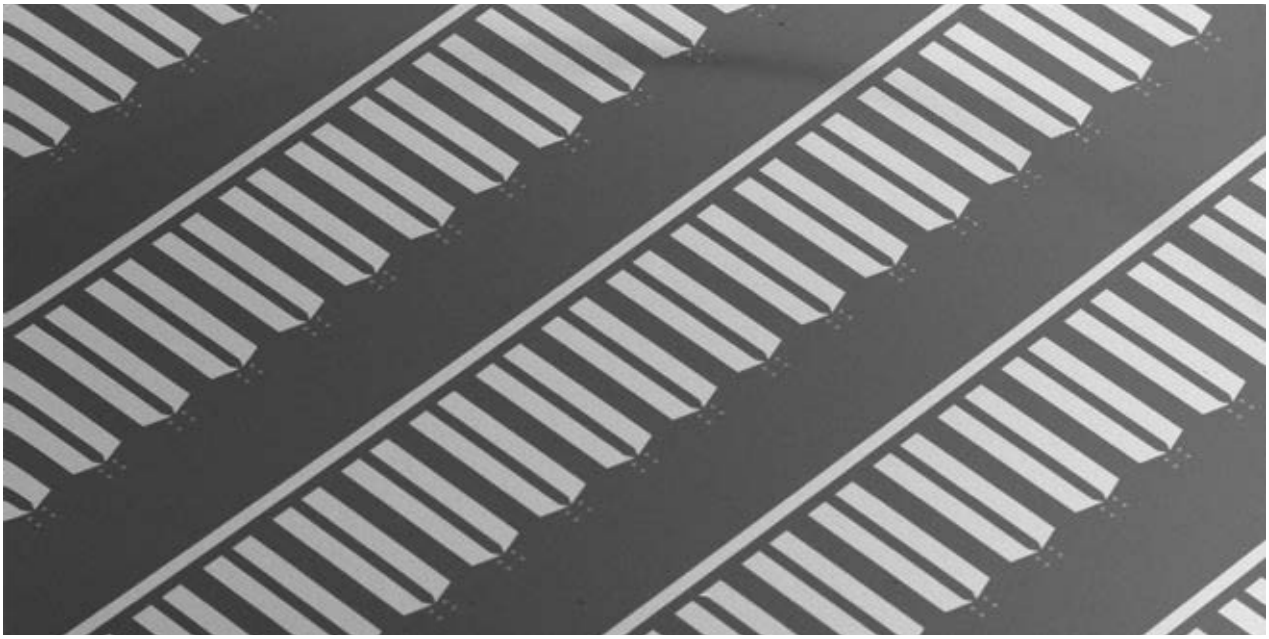
Harnessing the power of single photons

Generating and detecting single quanta of light energy is essential for many applications and disruptive technologies that will solve a number of challenges

Panagiotis Vergyris



The concept of photon counting is already a century old. However, we have only managed to harness its power over the last few decades. Generating and detecting these single quanta of light energy is essential for many applications and disruptive technologies that will solve many of today's global challenges, from super-efficient photonic quantum processors and ultrasecure communication to highly accurate sensors for biomedical imaging. Single-photon generation and detection technologies are redesigning the map of photonics applications.

▲ **Fig. 1** Their unique technology allows Pixel Photonics to incorporate hundreds of SNSPDs on a tiny chip. Here: a scanning electron micrograph of a test chip. (Source: Pixel Photonics)

Single-photon sources emit light as single particles or photons, unlike coherent and thermal light sources such as lasers and incandescent light bulbs. Ideally, a single photon source should produce single-photon states with 100 % probability and optical vacuum or multiphoton states with 0 % probability. Additionally, the emitter needs to be efficient, robust, easy to implement and able to produce single photons on demand, as provided by solid-state emitters such as quantum dots, color centers and carbon nanotubes.

Photon counting is a technique in which individual photons are counted using a single-photon detector (SPD). In contrast to a normal photodetector that generates an analogue signal proportional to the photon flux, a single-photon sensor emits a signal pulse for each detected photon. The number of pulses can be counted, giving an integer number of photons seen per measurement interval. This enables SPDs to make ultra-precise and accurate measurements and has made them the go-to solution for various applications. Most recently, SPDs have been used to implement quantum key distribution systems, detect entangled photons, and calibrate the single-photon generators needed. SPDs are required in quantum computing to detect photonic qubits. In addition, biomedical imaging can profit from using SPDs to identify and track individual biomolecules, such as proteins, DNA or tumor cells.

Not surprisingly with such technological developments, we have observed

a growing number of companies entering the single-photon sector in the last few years. In the remainder of this article, we will look at the contributions of some of them in the three areas of single-photon generation, detection and associated enabling technologies.

Single photon generation

I want to highlight that by actively demultiplexing a stream of single photons into different spatial modes, the door is opened to the possibility of conducting quantum computing and advanced quantum sensing. **Quandela**, a developer of quantum light sources and photonic quantum computing solutions provider from Paris, France, is working in this direction. Prometheus, Quandela's first stand-alone quantum light source, is the core that breathes life into quantum technologies. Its unique design and fiber-pigtailing technique allow high integration in a plug-and-play, 19-inch device. Prometheus consists of fully-integrated cryogenics, optoelectronic modules and solid-state sources and delivers high-quality photonic qubits for quantum information processing.

Sparrow Quantum, a Copenhagen-based company, provides a single-photon source chip as a scalable solution for efficient photon generation, based on a GaAs platform with InAs quantum dots embedded in photonic crystal nanostructures (Fig. 2). Precise control over the environment around the quantum dot has led to the world's highest fidelity of single-photon generation, enabling multiphoton interactions. The next step for Sparrow Quantum is to develop a user-friendly single-photon source providing a plug-and-play experience, enabling customers to focus on their research.

Aegiq, headquartered in Sheffield, UK, provide sources of indistinguishable and entangled photons operating at both near-infrared (900 – 1000 nm) and telecommunications wavelengths (o-band and c-band). Their technology is based on semiconductor quantum dots (QDs) that emit deterministically single photons, i.e. each trigger pulse results in a single-photon emission from the device. Aegiq's approach utilises a combination of fiber-coupled photonics, nanophotonic waveguides and microresonators to enable sources with high brightness, purity and indistinguishability.

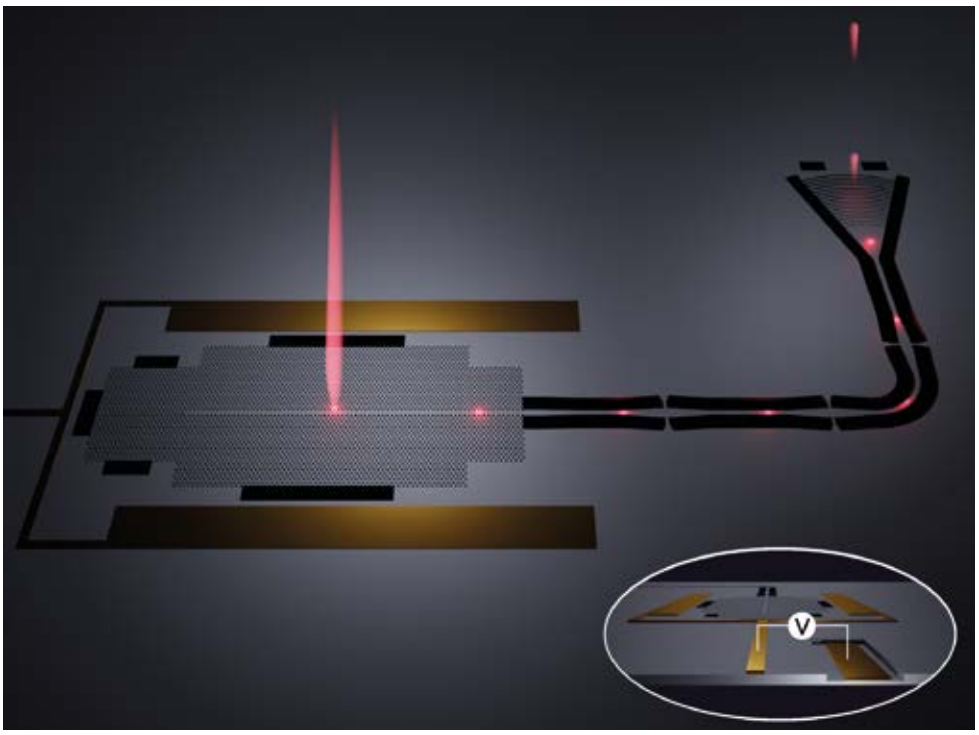


Fig. 2 Sparrow Quantum's single photon source: quantum light is generated by exciting a quantum dot inside the photonic crystal. The generated light is then guided along with the chip through the waveguide with record-high fidelity. An ultralow-noise environment is achieved by applying an electric field across the quantum dots. (Source: Sparrow Quantum)

Single photon detection

In today's modern world, the technologies we use in our everyday activities to monitor the world around us, to develop new medicines, or to produce the materials we use to build homes, offices, and factories, all rely on the most precise measurements of critical parameters. As the need for accuracy and precision has increased, optical measurement methods have become the default starting point to get the information we need. For many applications, systems now use single-photon detection to reach the required performance levels. Today, single-photon detection enables a variety of applications; these include particle sizing for industrial process control, lidar and range-finding, supporting applications from wind measurement and air monitoring for atmospheric aerosols and pollutants, helping cell phone cameras to find their focus, fluorescence detection and lifetime measurements for life science research, and flow cytometry for the detection of nanoparticles. With the development of silicon single photon counting from the original principle as discovered by engineers at RCA in the 1960s, and the launch of the world's first APD-based photon counting module in 1986, through to today's turn-key modules as developed by **Excelitas** – the successor of RCA – simple, plug-and-run photon detection can now be provided for original equipment manufacturer instruments and laboratories alike.

Aurea Technology is a leading European company providing key building blocks based on state-of-the-art photonics, including photon-counting detectors based on single-photon avalanche diode (SPAD) technology. Corresponding electronics, which operates above the breakdown voltage in Geiger mode and connected with active quenching circuits, allows the SPAD to detect extremely low light levels right down to single photons. SPAD photon-counting enables the detection of the most difficult-to-see events from longer distances and with much more precision. Its high performance and very high level of integration will allow SPAD technology to play a prominent role in many upcoming life improvement applications such as ultrasecure communications with quantum key distribution (QKD) and safer self-driving vehicles using lidar.

The Japanese company **Hamamatsu Photonics** can provide a complete range of single photon detectors spanning all technologies from SPADs/SPPCs to SiPMs/MPPCs, and PMTs. Solid-state photodetector SPPCs and MPPCs use

Fig. 3 ORCA-Quest qCMOSTM camera C15550-20UP (Source: Hamamatsu Photonics)

APDs (avalanche photodiodes) operating in Geiger mode. These detectors operate at low voltage and have a high gain, high photon detection efficiency, a high-speed response, excellent time resolution and a broad spectral response range with a low after-pulse, low cross-talk and low dark current count. In addition, they possess several advantages unique to solid-state devices, such as immunity to magnetic fields, a high resistance to mechanical shocks and immunity to 'burn-in' by incident light saturation. The company also has a range of scientific cameras, including the ground-breaking ORCA-Quest qCMOS photon-number-resolving scientific camera, which has an incredibly low noise of 0.27 electrons rms and a high pixel number of 9.4 megapixels (Fig. 3).

Imasenic from Barcelona, Spain, develops innovative custom CMOS image sensors, including sensors with SPADs. Being integrated into the image sensors, large arrays of SPADs can be created to provide imaging at ultra-low light levels. As the photon avalanche creation is fast, SPAD arrays can give the precise arrival time of photons, opening the way to highly integrated sensors for flash lidar. This technology is very interesting for autonomous driving, both for 3D-imaging of the environment and for driver status monitoring (DSM). Megapixel SPAD arrays can be used for ultralow light level photography, imaging, and quantum true random number generation (TRNG).

The Swiss company specializing in photon counting, **Pi Imaging Technology** (PIT), offers both small arrays and image sensors based on SPAD technology. Notably, the SPAD23 offers 90 Mcounts per second with 20 ps timing resolution. The SPAD512S offers up to 100,000 frames per second with zero readout noise. PIT also provides services for custom-designed SPAD arrays. SPAD sensors are finding applications in microscopy, quantum information, FLIM, and low-light and high-speed imaging.

Single Quantum, located in Delft in the Netherlands, has recently developed single-photon detectors based on superconducting nanowires (SNSPDs), showing specifications that reach the physical limit: near-unity detection efficiency, GHz count rates, almost no noise, and picosecond time resolution. The main applications are quantum cryptography and computers, and biomedical imaging. In biomedical imaging, a much larger depth can be reached by using Single Quantum's infrared single-photon detectors compared to conventional sensors, which allows the prediction or the prevention of certain diseases and offering better care.

Pixel Photonics, based in Münster, Germany, has developed a unique approach to integrate SNSPDs on a chip waveguide. They combine the superior features of SNSPDs with the versatility of an integrated photonic platform to deliver highly parallelized, efficient and ultrafast single-photon detection. Pixel Photonics' technology is agnostic to the platform. This allows SNSPD integration onto passive structures, on silicon nitride for instance, as well as with active components on lithium niobate (Fig. 1). While SNSPDs are inherently threshold detectors and insensitive to the number of photons in a detection event, waveguide integration and parallelization enable the use of SNSPDs for photon counting, paving the way for high-performance and scalable photonic quantum computing.

Looking to the future, single-photon detection will enable upcoming applications: increasing lidar range while ensuring the laser source remains safe for people's eyes in autonomous vehicles; for secure communications by detecting the single photons used for 1s and 0s in quantum key distribution (QKD) and by detecting entangled photons and calibrating the single-photon generators needed; in quantum computing, both by detecting the single photons used to generate or interrogate qubits; and many more.

Enabling technologies

Some of the technologies that enable the realization of easy-to-use single-photon sources and detectors are worth mentioning. **Teem Photonics** from Meylan, France, offers customized glass-based photonic circuits (also called planar lightwave circuits, PLC) through its ioNext platform. Its WAFT series (waveguide array to fiber transposers) enables high-performance integrated photonic packaging that has already found widespread use in optical communications and classical photonic computing. They are also perfectly relevant for quantum applications where coupling loss is paramount. These low-loss PLC components represent an ideal photonic platform to embed and efficiently couple various quantum emitters with fiber-compatible waveguides, as recently demonstrated with colloidal quantum dots by the Troyes University of Technology.

Icon Photonics, located in Paris, France, is a leading supplier of optical coupling and micro-packaging solutions. They have developed a wafer-level integrated packaging platform combining a silicon optical bench and a unique low-loss technology based on proprietary 3D polymer micro-optics. This platform is ideal for creating custom and reliable optical micro-benches, integrating fiber array coupling and maintaining systems, as well as high-speed electrical interconnects. These solutions promise a significant reduction in optical interconnection losses and cost, thanks to their high scalability. They are also available for a cryogenic environment and room temperature / high-temperature situations.

Nanoscribe, based in Karlsruhe, Germany, offers a unique 3D microprinting technology based on two-photon polymerization (2PP). Their new Quantum X align can print perfectly aligned (down to 100 nm lateral precision) optical microstructures, adapted in shape and size, directly onto active and passive components such as optical fibers and photonic chips. This enables the perfect transmission of light at chip level. The same technology has notably been successfully used at cryogenic temperatures for coupling single photons generated by quantum dots into a single-mode fiber [1]. The ability of 2PP to print 3D microstructures onto chips and fibers paves the way for further miniaturization of optical coupling and packaging solutions.

Currently, developing quantum-photonic components is tremendously costly, time-consuming and labour-intensive, owing to the lack of purpose-built, computer-aided design tools to guide the process. This means a component prototype must be built and improved upon over several iterations to meet the required performance. **Quantopticon** – based in Guildford, UK and Chicago, USA – is changing this by building Quantillion: the first comprehensive simulation suite empowering quantum-photonic engineers to rapidly manufacture optimized, high-quality, single-photon sources, qubits, and other devices for quantum-photonic information processing. The European Space Agency is also employing Quantillion to design a new generation of high-performance single-photon sources for the first European quantum encryption satellite, which will enable secure high-speed quantum key distribution.

Finally, the US company **Ansys,** through its Lumerical products, provides the drift-diffusion simulation of an electric field on a finite element mesh given the doping profile and the full-wave electromagnetic simulation of transmission and absorption, allowing dark count rate and photon detection efficiency simulations. Ansys Lumerical recently added an example to its application gallery on extracting the photon production spectrum from the secondary emission in the avalanche responsible for the internal and external crosstalk.

Conclusion

In this brief review, we have looked at the rapid progress made by mainly European companies working in single-photon generation and detection. Work on single-photon generation includes stand-alone quantum light sources with fiber-pigtailing that allows for compact integration, planar technology based on a GaAs platform for precise control and high fidelity generation as well as semiconductor quantum dots used in combination with fiber-coupled photonic waveguides and microresonators to enable sources with high brightness, purity, and indistinguishability.

On the detection side, there are detectors based on superconducting nanowire single-photon detectors (SNSPDs), which excel in key detector aspects such as quantum efficiency, bandwidth, count rates and especially low dark count rates. These devices and detectors based on single-photon avalanche diodes (SPADs) will be crucial for applications in quantum cryptography, quantum computing, industrial and biomedical imaging, safer self-driving vehicles with lidar and high-resolution, fluorescence-lifetime imaging microscopy.

Thanks to the many advantages of exploiting single photons as quantum information carriers, these technological developments, combined with advanced simulation software and advances in integrated photonic packaging, hold great promise for a global revolution in information processing that can solve many of today's global challenges.

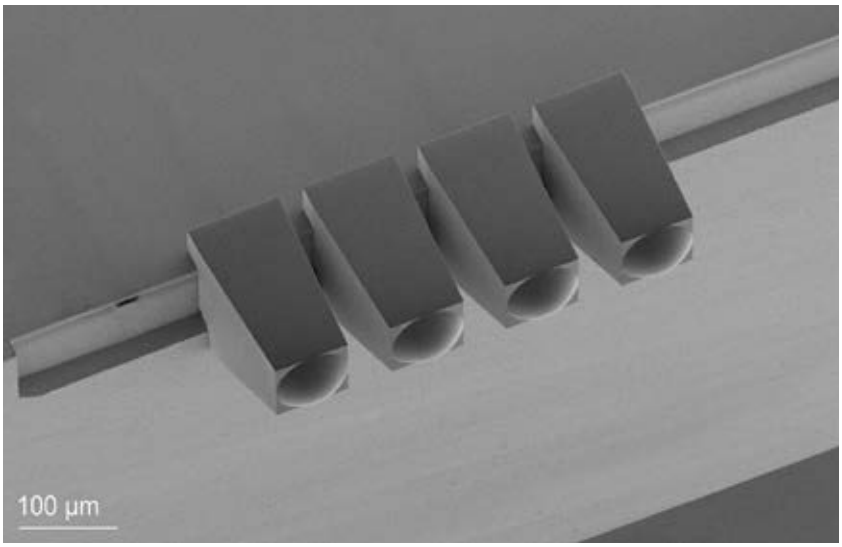


Fig. 4 SEM image of mode field shaping micro-optics aligned and printed with sub-micron precision onto the facet of a photonic chip. Sample of the research project HandheldOCT. (Source: Nanoscribe)

*

EPIC wishes to acknowledge its members and collaborators who are always eager to share their ambitions and vision, in particular Michel Antolovic, Pi Imaging Technology; Adrien Billat, Teem Photonics; Jenny Brown, Hamamatsu; Lola Courtillat, Aurea Technology; Sander Dorenbos, Single Quantum; Charles Goëller, Icon Photonics; Wladick Hartmann, Pixel Photonics; Mirella Koleva, Quantopticon; Bozidar Novakovic, Ansys; Maksym Sich, Aegiq; Richard Simons, Excelitas; Jörg Smolenski, Nanoscribe; Cecilie Toftdahl, Sparrow Quantum; and Renato Turchetta, Imasenic.

[1] 3D printed micro-optics for quantum technology: Optimized coupling of single quantum dot emission into a single-mode fiber, https://doi.org/10.37188/lam.2021.006

Author

Panagiotis Vergyris is a photonic technologies program manager at EPIC and works on sustaining a vibrant network with more than 800 corporate members active in photonics. He actively engages them and constantly supports 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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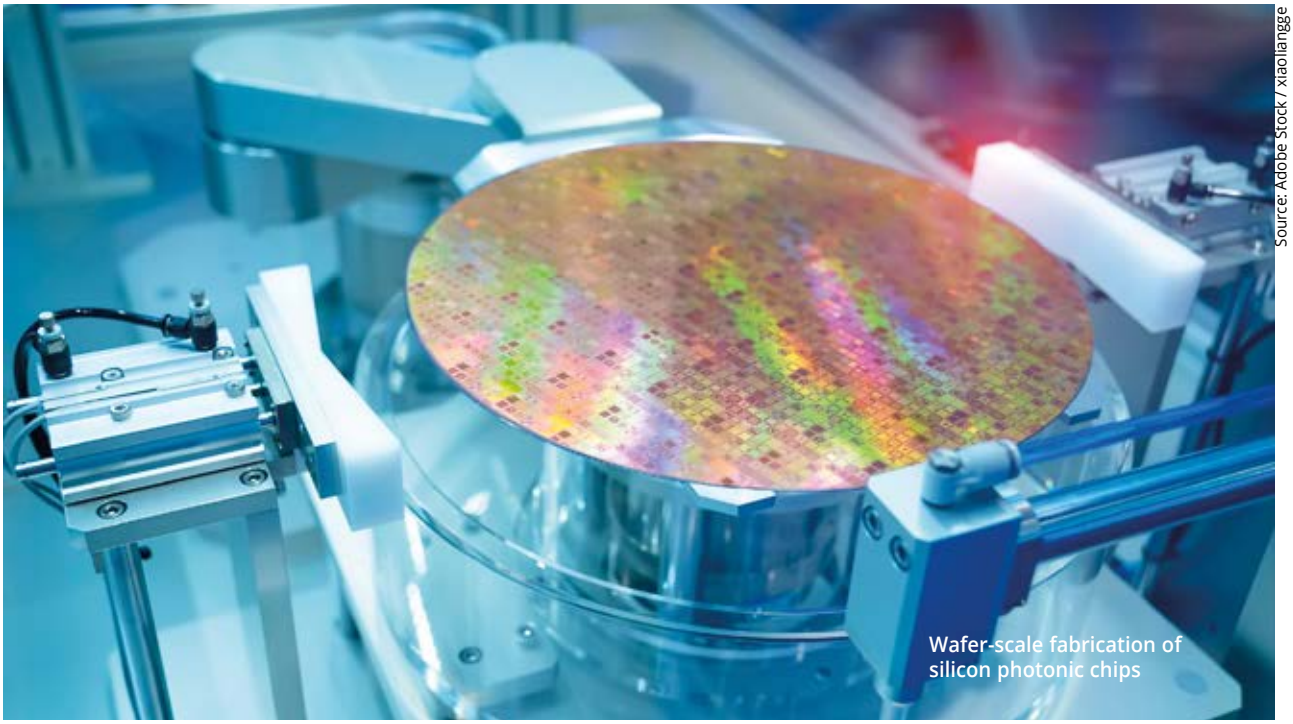
Programmable photonics for optical communications

Looking at silicon photonics from a different perspective

Ana Gonzalez and Jim Theodoras



Source: Adobe Stock / xiaoliangge

Wafer-scale fabrication of silicon photonic chips

As the bandwidth requirements in communication networks continue to increase unabated, wafer level photonic integration is becoming key to miniaturizing components and increasing the number of functionalities, thereby replacing bulky systems. However, a variety of challenges such as long development times and high costs of fabrication are impeding the widescale adoption of this technology in the optical communication field.

Programmable photonic integrated circuits (PICs) have emerged as a viable commercial alternative to overcome the drawbacks related to long-development times for Silicon photonics fabrication, speeding up the adoption of PIC technologies. In addition to speeding development cycles and lowering costs, programmable photonics adds the ability to move electronic processing into the optical domain as well as to parallelize tasks that right now are carried out by different and bulky devices. In this article we discuss the latest developments in programmable PICs, and their potential to become the breakthrough technology that will finally deliver on promises of drastically reduced power consumption in data centers and scaled-down infrastructure.

Silicon photonics – a dream always just out of reach

Optical aficionados may not realize that the current PIC boom is not the first but only the most recent. As 1999 millennium celebrations faded into memory early 2000, the real party began: silicon photonics funding. There was substantial investment into integrating light onto silicon circuitry during the early 2000s. There were many paths taken, such as making everything out of indium phosphide (InP), growing light emitting semiconductors on silicon wafers through selective area growth (SAG) and quantum well intermixing (QWI) to name just a few. They all had one thing in common: trying to get silicon to make light. Unfortunately for these early industry efforts, silicon proved incredibly stubborn in refusing to make light. Sometimes the laws of physics create an impenetrable barrier, and the bandgap of silicon would appear to be one of these fourth walls, at least for the time being.

Yet another hype, boom, bust cycle was relegated to the annals of history. And again in the 2010s … and again in 2020 … silicon photonics (SiPh) is

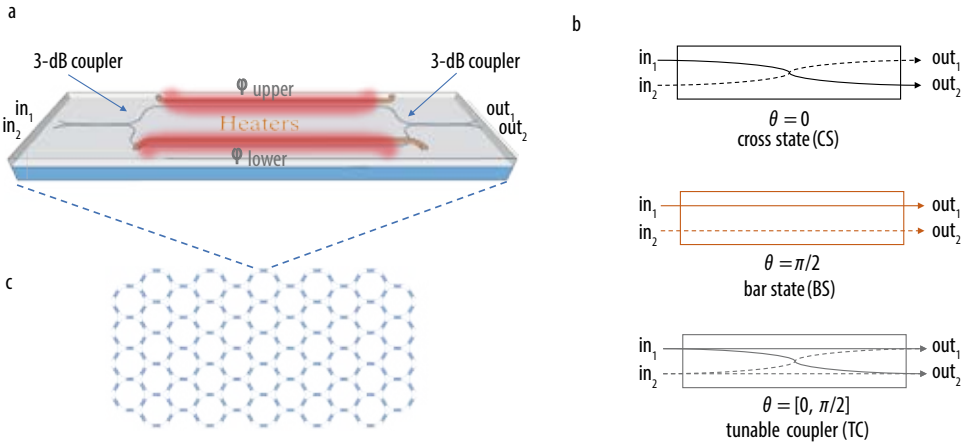


Fig. 1 Working mechanism of the photonic processor: (a) tunable coupler, (b) output control signal (crossbar, switch or variable coupler), and (c) hexagonal mesh

proving to be as cyclical as style trends such as hair length, hemlines and, dare I say it, corduroy pants.

So what has launched the most recent foray into the SiPh abyss? Giving up. Once the industry stopped trying to force silicon to do something it does not want to do, to lase, things started moving forward again. With a newfound focus on what can be done, rather than what is very difficult if not impossible, advances have been quick. Waveguides, modulators, oscillators, power combiner/splitters, wavelength selective combiner/splitters, photodetectors, thermal tuning, etc. the list goes on and on. The war was never really lost, but rather there was always a strategic retreat back to the trenches to focus on steady progress forward. And wow has there been a lot of progress made over the last few decades.

So, is now finally the time for silicon photonics to shine? Both yes and no. SiPh technology has finally evolved to the point where it not only works, but is compelling in lots of applications (sensing, computing, switching, processing, etc.) across a wide variety of industries (automotive, medical, datacom, telecom, environmental, artificial intelligence, space, etc.). And that is the crux of the problem. Demand has outstripped the ability of a fledgling SiPh industrial ecosystem to the point where growth is being severely stunted. SiPh designs often require multiple iterations as both process and design data is taken to zero in on a final set of working variables. At the time of writing, SiPh fabrication times for a single iteration alone can stretch from four to six months. When all the required steps for a final product are added up, the total fabrication time can exceed the anticipated product lifecycle time! Clearly a better solution is needed, and fortunately the answer now exists.

Photonic processors

Early silicon integrated circuits (ICs) faced a similar day of reckoning when growth reached a point that it was simply not possible to fabricate a custom IC for each and every application. General purpose processors and reconfigurable gate arrays were created that could be programmed as needed. Similarly today, the SiPh industry has grown to the point where general purpose photonic processors and reconfigurable functional arrays are needed. So how might these photonic processors be created out of today's SiPh technology?

Just as the key to the first programmable electronic gate arrays was a reprogrammable electrical interconnect array, the key to the first programmable photonic functional array is a reprogrammable photonic waveguide array. So far, different companies have been developing commercial devices based on programmable photonics, such as Lightmatter and Luminous for computing applications, and PsiQuantum and Quix for quantum. However, the use of programmable photonics for applications in the optical communication scene would require more flexible devices able to provide arbitrary path lights and to parallelize operations.

For optical communication applications, the programmable chip proposed by iPronics [1] consists of a Mach-Zenhder hexagonal mesh where each individual unit itself consists of an elementary 2×2 tunable photonic coupling component capable of providing an independent setting of the power coupling ratio and the phase shift experienced by the incoming signals from two input waveguides in their transition to the two output waveguide ports of the devices. These coupling components can create integrated waveguide meshes: the waveguides are connected by means of

Companies

iPRONICS

iPRONICS is developing the first general-purpose photonic processor that shares a common hardware platform based on photonic integrated circuits that is reconfigurable by software. This cost-effective solution enables the same hardware to be applied to limitless commercial applications with increasing needs in computational power, including 5G communication, data centers, artificial intelligence, autonomous driving, quantum computing, and Internet of Things.

https://ipronics.com

HGGenuine

The Top 10 optical transceiver manufacturer has shipped over eighty million transceivers in 2021. It is a subsidiary of HG Tech, a manufacturing conglomerate listed on the Shenzhen Stock Exchange with a market capitalization of nearly $ 3 B. HGGenuine is a pioneer in optoelectronic device development with advanced end-to-end production lines, and vertical integration capabilities from chip, device, transceiver to subsystems. It has opened a new $ 100 M datacom factory bringing manufacturing floorspace up to nearly 1 M square feet, and recently announced a large and rapidly-growing internal silicon photonics team.

https://en.genuine-opto.com

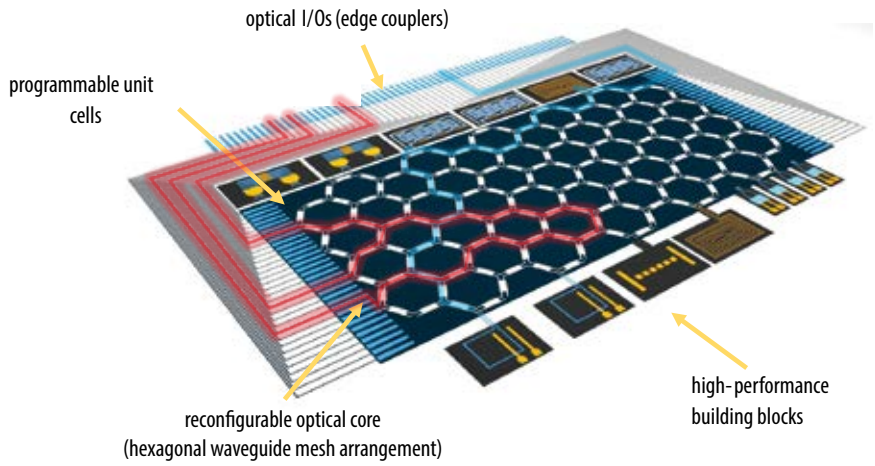


Fig. 2 Photonic processor consisting of the programmable mesh, the building blocks surrounding the hexagonal mesh and the input/output ports

a beamsplitter/tunable coupler (Fig. 1a) that can be operated by means of an output control signal (crossbar, switch or variable coupler) with independent power division ratio and phase shift (Fig. 1b). At the minimum, a simple photonic crossbar switch is created. However, the matrix formed is much more powerful than it seems at first glance as it also enables the synthesis of any kind of optical core circuit topology, including finite (FIR) and infinite impulse response (IIR) multiport interferometers and filters. A hexagonal mesh is potentially the most flexible approach to implement the programmable photonic circuit concept (Fig. 1c).

Leveraging a reprogrammable optical waveguide array, functional blocks can now be arranged around the switch matrix and interconnected as needed. These functional blocks can be active elements such as lasers, modulators and optical amplifiers that can be added to the chip by hybrid integration of InP and SiPh. Other passive components could also be added as building blocks, such as an array waveguide grating or some higher order filters. In this example, the device contains 64 input/output ports (Fig. 2), although the matrix can be scaled up or down indefinitely.

Taking into account that the programmable mesh can interconnect photonic functions, what sorts of devices can be realized?

Photonic processors for optical transceivers

One important industry driver of the SiPh ecosystem is optical transceivers. As bandwidth requirements have exceeded the ability of single channel systems to keep up, the industry has turned to parallelism. This has created the challenge of fitting large photonic component counts into existing power and space budgets. SiPh solves this challenge, but at the cost of inflexible designs and long fabrication cycles.

Photonic processors greatly alleviate a lot of the pain points of using SiPh for optical transceivers. The optical functions can be simulated ahead of a component's availability to get a head start on design decisions. Different functions can be looped together as needed during engineering bring-up to test each feature individually. For example, if only one DSP channel is working, it can be routed to each optical channel one after the other, or vice-versa. If design tweaks are needed, most can be accommodated by simple reprogramming on the spot rather than initiating a four-month re-spin. Similar benefits are enjoyed during manufacturing. If all the parallel channels need balancing, it is a simple matter of reprogramming rather than manually reworking a laser. A script that reprograms loopbacks and test paths can be written to cover a 100 percent test of the functionality.

There are even potential benefits in the field. As component counts inside optical transceivers have climbed, the impact of a single failure has grown as well. There are dozens of optical functions inside a transceiver, and it only takes one failure to bring down all the channels. With photonic processors, extra components can be included as a backup as part of the design, manufacturing, and test processes. For example, an extra laser can be included, and the spare can be switched in if a laser does fail prematurely.

Truly capturing the power of programmable photonic processors requires thinking beyond today's paradigms. Today, many optical transceiver types only have small photonic differences between them. It is entirely possible to make a generic optical transceiver whose final product type is programmed after manufacturing. In fact, the transceivers could be produced, shipped, and stored in this benign state and, upon plugging them into the host, they are programmed to be the transceiver type required.

Photonic processors for optical networking

The parallelization of tasks is another benefit that photonic processors can provide. Clearly, this novel programmable device can act as an optical switch, able to route light between different input and output ports. Less obvious is that it enables the powerful features of network broadcasting and multicasting. Point-to-point and point-to-multipoint communication and any kind of combination of inputs and outputs are only limited by the physical size of the mesh and accumulated losses. In addition to just routing light around, ring filters and ring resonators can be emulated inside the mesh. Now the device becomes a reconfigurable optical add-drop multiplexer (ROADM) with the ability to remotely switch traffic from a wavelength-division multiplexing (WDM) system at the wavelength layer. This allows individual or multiple wavelengths carrying data channels to be added and/or dropped from a transport fiber without the need to convert the signals on all the WDM channels to electronic signals and back again to optical signals. To be able to implement nearly any optical communication network function into a programmable photonic device implies that the software-defined network (SDN) control plane will have total flexibility to allocate resources. By using a single SiPh chip, the possibilities for radically changing optical communication networks are endless.

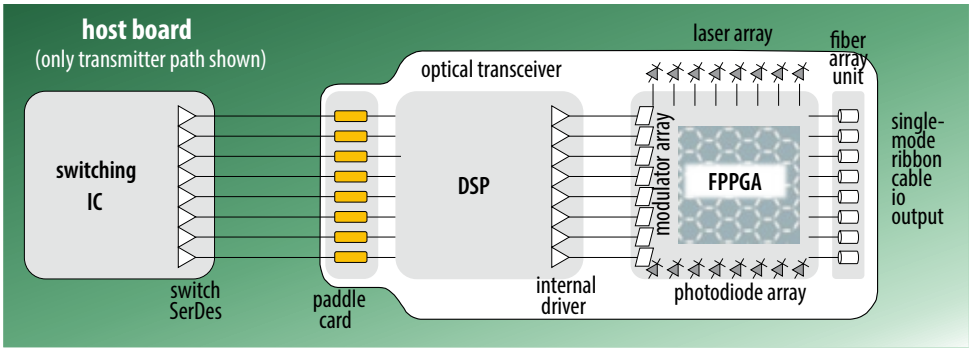


Fig. 3 Generic optical transceiver using a photonic processor for the TROSA (transmitter receiver optical subassembly)

Photonics processors for optical digital signal processing

Electronic digital signal processing has become an important part of optical communications. Direct-detect fiber optic transmission has moved to complex modulation types that need DSPs to decode as well as to compensate for channel nonlinearities. Coherent fiber optic transmission requires DSPs for intradyne computations as well channel nonlinearities. As data rates have increased, power per bit has not fallen as fast as expected due to the need to add DSPs to the channel.

Programmable photonic processors have the unique ability to perform a wide variety of DSP functions on-the-fly in the optical domain, thus offloading the electrical DSP and decreasing its power consumption. A short list of capabilities related to coherent transmission includes:

- correcting timing skew as the impact of non-ideal time synchronization between in-phase and quadrature electrical signals can be critical in multi-subcarrier systems,
- dispersion compensation where fluctuations due to combined phase noises from the source and local oscillator degrade the performance of both homodyne and heterodyne systems,
- channel equalization including a means for their realization for both quasi-static and dynamic channel impairments,
- equalization of IQ path and imbalance in responsivities at the balanced detections.

Today coherent transmission is thought of as a long reach technology for connecting cities, states, countries, even continents, primarily due to the amount of power required by all the electronic DSP processing. There has been much industry talk about leveraging coherent techniques for shorter reach applications, such as within a data center, but power requirements have made this prohibitive. Programmable photonic processors have the potential to offload the electronic DSP and provide both the power savings and inherent flexibility needed to expand coherent technology from under the world's oceans to between data center equipment racks.

The future is photons

The future of SiPh becomes less murky when we look at silicon electrical integrated circuit markets today. The IC market is served by ASSPs, ASICs, FPGAs, and CPUs. Optical discrete components and functional blocks are analogous to ASSPs. Large PICs dedicated to a single product are analogous to ASICs. What integrated optics are currently lacking are analogous to FPGAs and CPUs. Reprogrammable optical functional arrays and photonic processors will fill this gap in market needs and be the impetus that takes SiPh technology from limited use in niche markets to a not-so-distant future where photons work hand-in-hand with electrons to achieve what has previously been thought impossible.

*

iPronics wants to acknowledge our partner Synopsys for their support in the simulation and design of the Mach-Zehner mesh of the iPronics photonic processor.

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[1] *D. Pérez-López* et al.: Multipurpose self-configuration of programmable photonic circuits, Nat. Comms., 10.1038/s41467-020-19608-w, 2020

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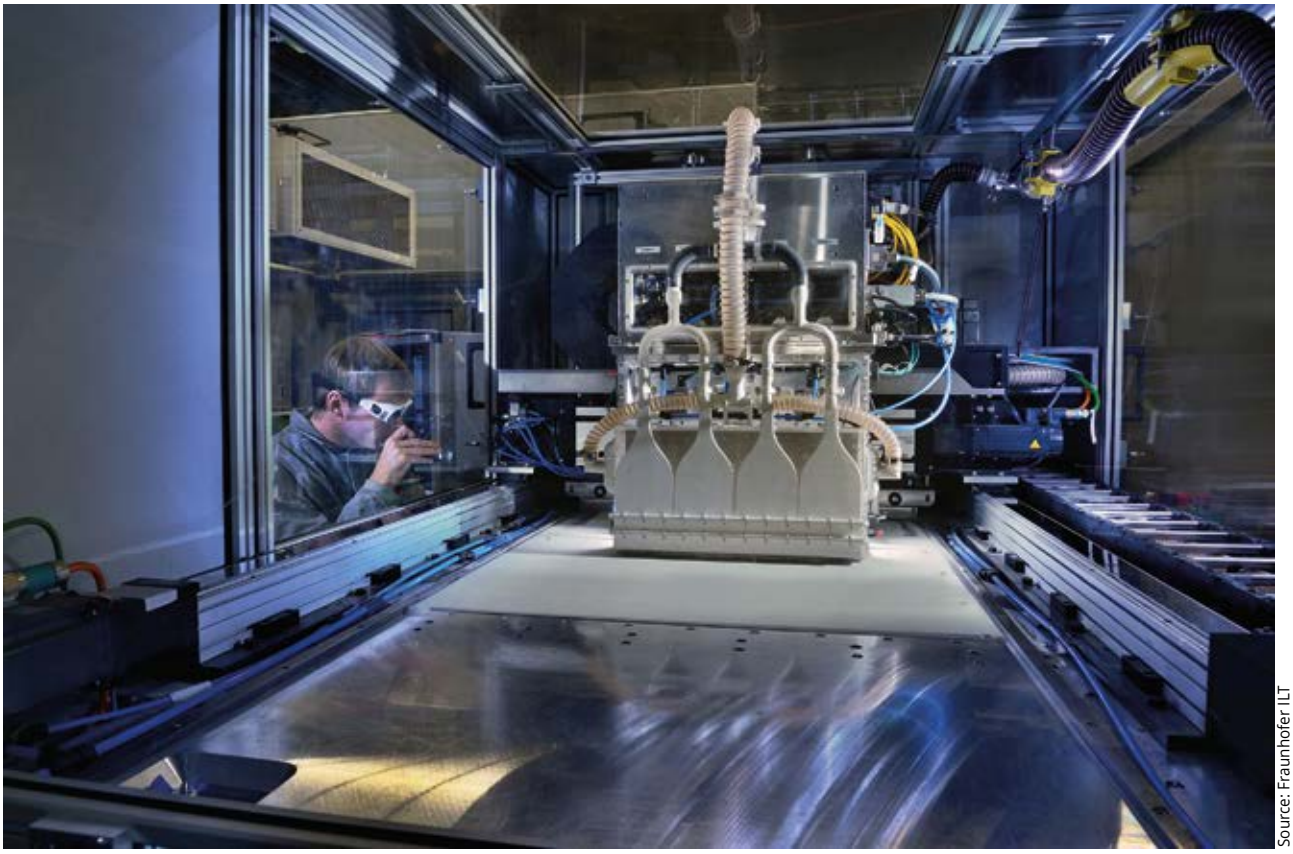
Not without my AI

Virtual chain reactions – live, in color and in person



Source: Fraunhofer ILT

Many industries are ready to break new ground in production with lasers. To do this, users and suppliers must reconcile digitalization and sustainability, ecology and economy. As an important means to this end, lasers can be integrated into the emerging process chains so that they interact with the entire upstream and downstream processes, saving both time and money. The more than 520 participants at the AKL'22 International Laser Technology Congress in Aachen learned how the laser community is already proactively tackling these tasks.

Deep learning, cloud computing, virtual commissioning – three of many new terms at AKL'22 that pointed toward the changing nature of how lasers are and will be used. Digitalization used to come up at the Aachen insider meetings of the laser community, but suddenly it was ever-present: Everywhere, AKL participants discovered the beginnings of what digital photonic production (DPP) of the future might look like.

But what makes manufacturing under the DPP label special – is it particularly efficient, safe, competitive and, at the same time, can it learn? A new term was brought into play by Prof Constantin Häfner, director of the Fraunhofer Instutute for Laser Technology, ILT: "Sustainability is increasingly becoming an important criterion for how decisions are made in the manufacturing environment. Sustainable digital photonic manufacturing opens doors for technology sovereignty, innovation, resilience, and agility." Sustainable digital photonic production has many advantages: Not only does it help users implement sustainable goals and regulations, but it also strengthens Europe's role as a high-tech location.

▲ XXL on-the-fly: Fraunhofer ILT demonstrated how a gantry system can use the laser powder bed fusion process to produce large stainless steel components at AKL'22 by 3D printing a 300 mm high Rolls-Royce turbine component with a diameter of 650 mm.

Lasers just for fun: Is competition from Google & Co. looming?

The laser industry is facing competition from the big players in the digital industry. Apple, Google and Facebook, for example, are currently said to be hiring laser physicists on a grand scale to build – not only cars, rockets or satel-

Source: AKL e.V., Andreas Steindl

Prof Dr Constantin Häfner, director of the Fraunhofer Institute for Laser Technology ILT, was pleased to host lively discussions during AKL'22.

lites – but soon lasers as well, all 'just for fun'. AKL participants learned this astonishing news at the traditional Gerd Herziger Session "Laser Beam Source Development – Quo vadis?"

This is reason enough for laser manufacturers to improve their market position. At the session, Dr Christian Schmitz (CEO Laser Technology, Trumpf), Mark Sobey (executive vice president and COO, Coherent) and Volker Krause (managing director, Laserline) spoke in favor of very extensive digitalization, without which no laser manufacturer could survive. Indeed, their customers show great interest in this and want to use data from laser applications to find the perfect process window to further increase value creation. In the future, the laser must be smarter, easier to integrate and easier to use.

Targeted planning of AI deployment

The subsequent session on "Digitalization in Photonic Production" with Dr Joachim Döhner (senior director global sales, Kuka Systems), Dr Jens Ottnad (R&D head data and AI, Trumpf Machine Tools) and Dr Tobias Kamps (corporate technology, Siemens) also offered startling insights. In unison, the speakers noted that entrepreneurs should no longer ask themselves whether they want to use digital tools such as AI. Now it is only a matter of when and how, because only with targeted, clever digitalization can they continue to exploit how photonic production can be most usefully applied.

The goal is attractive, but the path to it is a dangerous tightrope walk: On the one hand, newcomers should not approach the topic half-heartedly, but should also include upstream and downstream processes when digitalizing their processes. On the other hand, they should not approach the task naively and overdo it. Otherwise, they run the risk of 'drowning in a sea of data'.

Digitalization is particularly in demand when users break new ground. This is particularly true of additive manufacturing, which is about to clear the biggest hurdle – entry into large-scale automotive production. At the AKL's Additive Manufacturing Forum, manufacturers of space engines, automobiles, materials and software, among other things, examined the current situation from a variety of perspectives. Their core message: Additive manufacturing has grown up, but fine-tuning is now the order of the day.

Three tips from 3D printing practice

Close the loop is what Dr Bart van der Schueren, CTO of Materialise NV, Leuven, recommended: "Although 3D printing is inherently a digital process, often only the 'CAD-to-print' route is used. But if users close the loop, they can effectively engage in a continuous 'plan-do-check-learn' process thanks to feedback."

Lower material usage with simulation is what Keno Kruse, account manager of Cadfem, Hannover, Germany, suggested: "By using simulation, users can identify critical areas in advance and take measures before printing – saving both time and money. Ansys offers world-class simulation software to optimize LPBF, DED and metal binderjet sintering processes."

Pay attention to powder selection and stiffness is what Raphael Koch, additive manufacturing research engineer at Ford-Werke in Aachen, said when referring to his initial experience in developing functional LPBF prototypes for the chassis area: "Using powder from the market reduces development time and costs. The printed components should have similar properties to conventional sheet metal for chassis. The yield strength should be 700 to 800 MPa, the elongation more than 10 % and the density 7.85 g/cm³."

Inline quality assurance: analysis during the manufacturing process

The research project "DigitalCMM Digital Coordinate Measurement Machine" is showing just what such a solution can look like [1]. A consortium of Camaix, Point 8, Oculavis as well as BCT and the Fraunhofer Insti-

Institution

Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft based in Germany is the world's leading applied research organization. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. A trailblazer and trendsetter in innovative developments and research excellence, it is helping shape our society and our future. Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Over 30,000 employees, predominantly scientists and engineers, work with an annual research budget of € 2.9 B. Fraunhofer generates € 2.5 B of this from contract research.

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tute for Production Technology IPT have developed a concept for evaluating machine-integrated measurement data in milling technology.

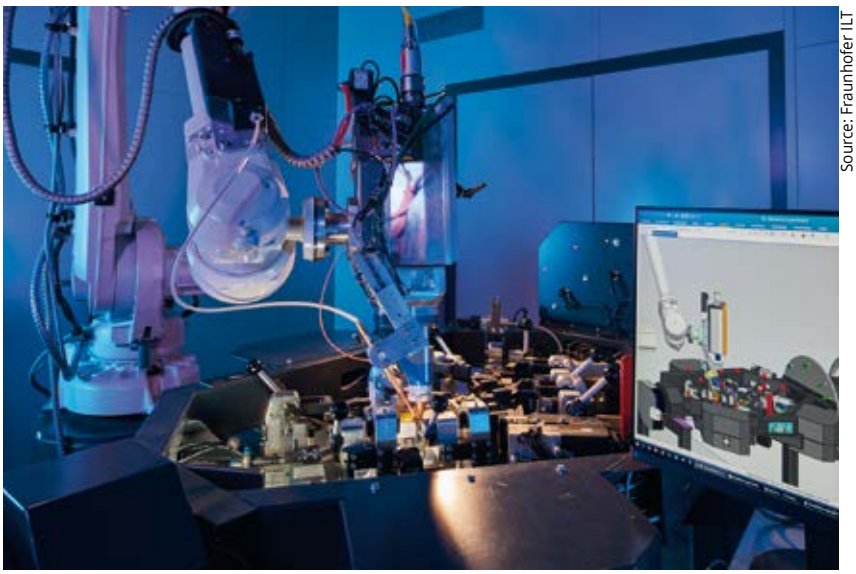
With a joint solution from the partners BCT as software manufacturer and Point 8 as AI specialist in the consortium, the partners have demonstrated that their solution can acquire spatially resolved process data from a 5-axis milling machine at high frequency. An AI-based analysis of the recorded data allows them to draw conclusions about the process quality of the individual components. Process properties and component geometry can be automatically recorded and analyzed thanks to the geometric measurement technology – in the project, a measuring probe – which is also connected to the software within the machine.

But how does one generally deal with the constantly growing volume of data that is collected in sensor networks, for example? "With suitable data acquisition strategies, the information content that can be evaluated is growing and increasing automation of the evaluation is becoming possible," said Jan Bremer, looking optimistically to the future. "In the future, we may only need significantly smaller amounts of data in production, as suitable algorithms and machine-integrated data acquisition go hand in hand to help us draw relevant conclusions with increased efficiency."

Current research projects such as the "ProSLAM" project [2] are investigating how to integrate a large number of different sensors for process and geometry and merge them with external measurement data such as CT images of additively manufactured components. Bremer expects great progress for process understanding and the user-friendly automation of development and production processes based on this by establishing machine-integrated sensor networks.

Will costly big data analysis soon be superfluous?

But how does one generally deal with the constantly growing volume of data collected by sensor networks, for example? "With suitable data acquisition strategies, the information content that can be evaluated is growing and increasing automation of the evaluation is becoming possible," said the R&D manager Jan Bremer, looking confidently to the future. "Perhaps in the future we will only need significantly smaller amounts of data in production, as suitable algorithms and machine-integrated data acquisition go hand in hand to draw relevant conclusions with increased efficiency."



Source: Fraunhofer ILT

Fraunhofer ILT scientist Martin Dahmen on the EFRE.NRW project MultiPROmobil: "The whole thing results in a flexible work cell that can be reconfigured with scalable manufacturing systems and Profinet connection to the digital twin."

Intelligent and adaptive detection of the entire process chain could also help make supply chains more reliable, he said. "If every single module in the process chain works adaptively and intelligently, the failure of a casting process, for example, can easily be replaced by an additive process," said Bremer, describing the exciting alternative. "The failure is then unproblematic because the adaptive process chain automatically reacts and adjusts to the replacement to achieve the desired end result."

The EFRE.NRW project MultiPROmobil is also entering hybrid-additive new territory. Under the coordination of Fraunhofer ILT, project partners have developed multifunctional laser tools for cutting, welding and laser material deposition with wire (w-LMD), an innovation that generated a lot of interest during the demonstrations at Fraunhofer ILT during AKL'22: These tools are ultilized in a cell for multifunctional laser robot technology, which is designed to interact with a digital twin to flexibly and economically produce sheet metal assemblies for electric vehicles.

The driving factor is the trend towards small batch sizes, wide variety, and dynamic product life cycles. As a result, the complexity of design and the scope of functions increases. The project partners are, therefore, focusing on the benefits of digital transformation. ILT scientist Martin Dahmen described the goal as follows: "The whole thing culminates in a work cell that is not only flexible that can be reconfigured with scalable manufacturing systems and Profinet connection to the digital twin."

Human interface

The ensemble of humans and robots is a particular challenge because the operation is not only automatic but also partly manual. "We have to bring manual functions together with automatic operation," Dahmen explained. "For this purpose, there is an operator panel in front of the machining cell as a user interface, on which the operating personnel can intervene manually or start the process, for example, when changing workpieces."

[1] https://www.ipt.fraunhofer.de/en/projects/digitalcmm.html
[2] https://www.ProSLAM.de

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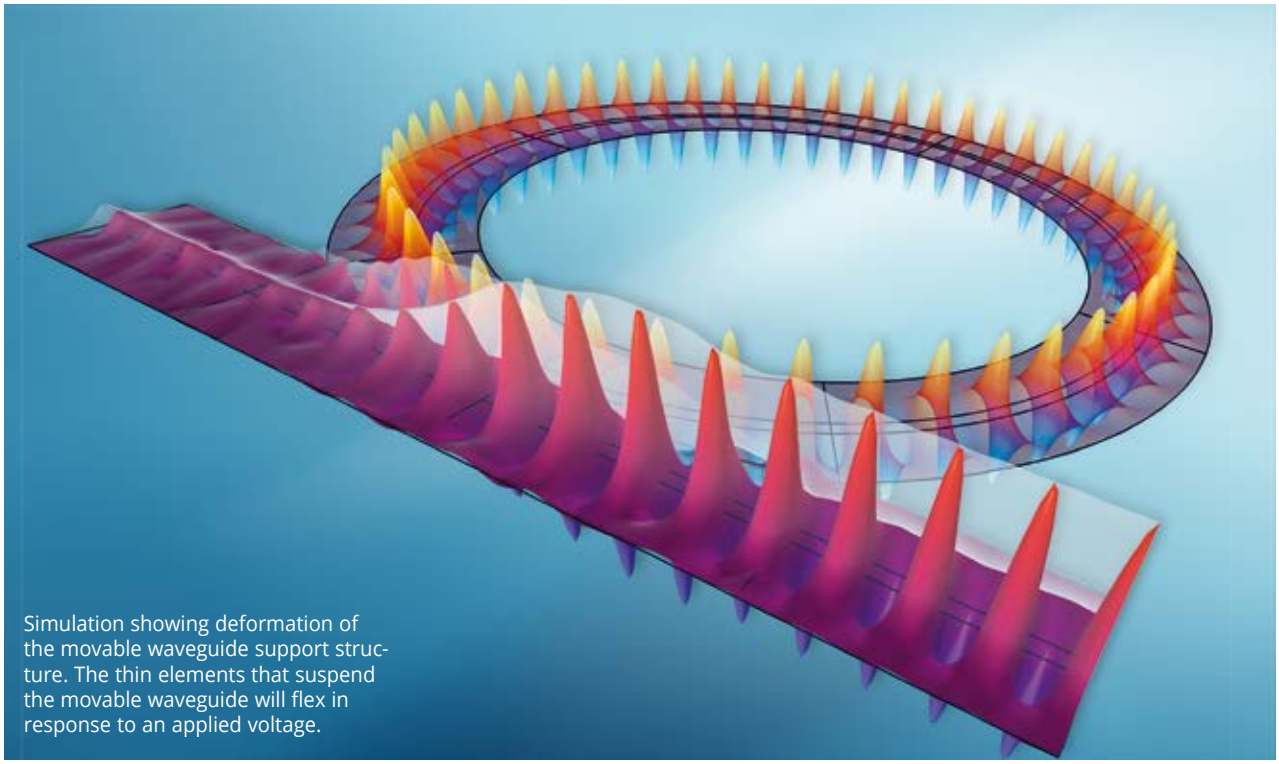
Photonic devices for future network designs

Designing a silicon photonic MEMS phase shifter with simulation

Alan Petrillo



Simulation showing deformation of the movable waveguide support structure. The thin elements that suspend the movable waveguide will flex in response to an applied voltage.

Optical fiber networks, which make up the backbone of the internet, rely on many electrical signal processing devices. Nanoscale silicon photonic network components, such as phase shifters, could boost optical network speed, capacity, and reliability. To design these small but powerful devices, a team at the Swiss Federal Institute of Technology Lausanne uses simulation to optimize both optical and electromechanical performance.

The modern internet-connected world is often described as wired, but most core network data traffic is actually carried by optical fibers – not electric wires. Despite this, existing infrastructure still relies on many electrical signal processing components embedded inside fiber optic networks. Replacing these components with photonic devices could boost network speed, capacity, and reliability. To help realize the potential of this emerging technology, a multinational team at the Swiss Federal Institute of Technology Lausanne (EPFL) has developed a prototype of a silicon photonic phase shifter, a device that could become an essential building block for the next generation of optical fiber data networks.

Lighting as a path

Using photonic devices to process photonic signals seems logical, so why is this approach not already the norm? Hamed Sattari, an engineer currently at the Swiss Center for Electronics and Microtechnology CSEM specializing in photonic integrated circuits (PI) with a focus on microelectromechanical system (MEMS) technology, was a key member of the EPFL photonics team that developed the silicon photonic phase shifter [1, 2]. In pursuing a MEMS-based approach to optical signal processing, Sattari and his colleagues are taking advantage of a new and emerging fabrication technology. "Even ten years ago, we were not able to reliably produce integrated movable structures for silicon photonics and MEMS are becoming more achievable with the current manufacturing capabilities of the microelectronics industry. This might transform the optical fiber network infrastructure," he says.

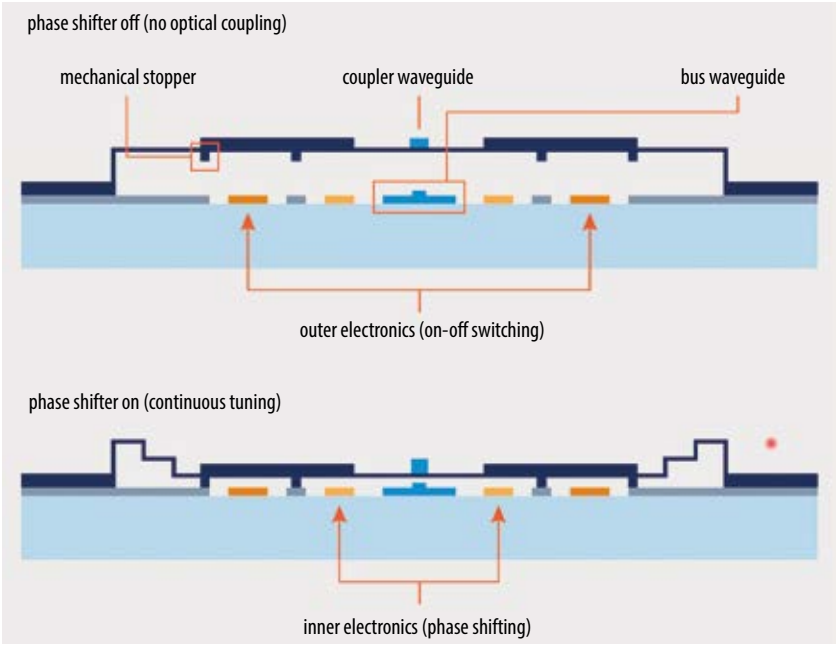
The phase shifter design project is part of EPFL's broader efforts to develop programmable photonic components for fiber optic data networks and space applications. These devices include switches, chip-to-fiber grat-

ing couplers, variable optical attenuators (VOAs), and phase shifters, which modulate optical signals. For this application, existing optical phase shifters tend to be bulky or suffer from signal loss. MEMS actuation of movable waveguides could modulate an optical signal with low power consumption in a small footprint.

How to modulate optical signals

The MEMS phase shifter is a sophisticated mechanism with a deceptively simple-sounding purpose: it adjusts the speed of light. To shift the phase of light is similar to slowing it down. When light is carrying a data signal, a change in its speed causes a change in the signal. Rapid and precise shifts in phase will thereby modulate the signal, supporting data transmission with minimal loss throughout the network. To change the phase of light traveling through an optical fiber conductor, or bus waveguide, the MEMS mechanism moves a piece of translucent silicon called a coupler into close proximity with the bus.

The design of the MEMS mechanism in the phase shifter offers two stages of motion (Fig. 1). The first stage provides a simple on-off movement of the coupler waveguide, thereby engaging or disengaging the coupler to the bus. When the coupler is engaged, a finer range of motion is then provided by the second stage. This enables tuning of the gap between the coupler and bus, which allows precise modulation of phase change in the optical signal (Fig. 2). The coupler is made from silicon with a high refractive index. When the two components are coupled, a light wave moving through the bus will also pass through the coupler, and the wave will slow down. If the optical coupling of the coupler and bus is not carefully controlled, the light's waveform can be distorted, potentially losing the signal – and the data.



Source: EPFL, CC BY 4.0

Fig. 1 Two stages of motion for the MEMS mechanism in the phase shifter

Designing at nanoscale

The challenge for Sattari and his team was to design a nanoscale mechanism to control the coupling process as precisely and reliably as possible. As their phase shifter would use electric current to physically move an optical element, Sattari and the EPFL team took a two-track approach to the device's design. Their goal was to determine how much voltage had to be applied to the MEMS mechanism to induce a desired shift in the photonic signal. Simulation was an essential tool for determining the multiple values that would establish the voltage versus phase relationship. To solve this complex multiphysics problem, the COMSOL Multiphysics software provided many options for breaking the large problem into smaller tasks. The EPFL team conducted simulations in two parallel arcs, using the RF Module for optical modeling and the Structural Mechanics Module for electromechanical simulation.

The optical modeling (Fig. 3) included a mode analysis, which determined the effective refractive index of the coupled waveguide elements, followed by a study of the signal propagation. The light was to enter and exit the device with only the desired change in its phase. In this way, the team determined the eigenmode of the system in Comsol.

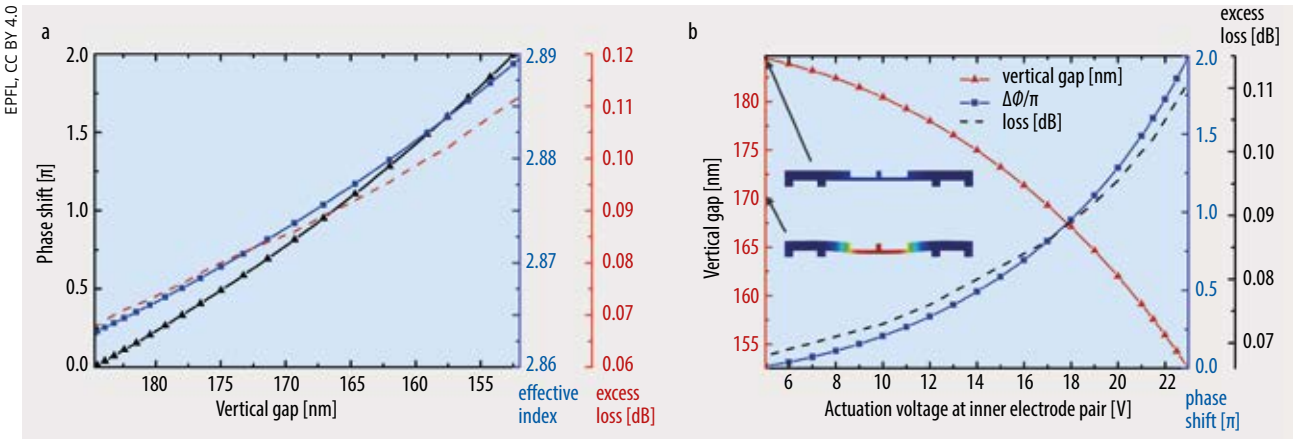


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Fig. 2 (a) The optical simulation established the vertical distance between the coupler and waveguide that would result in a desired phase shift in the optical signal. (b) The electromechanical simulation determined the voltage which – when applied to the MEMS mechanism – would move the coupler waveguide to the desired distance from the bus.

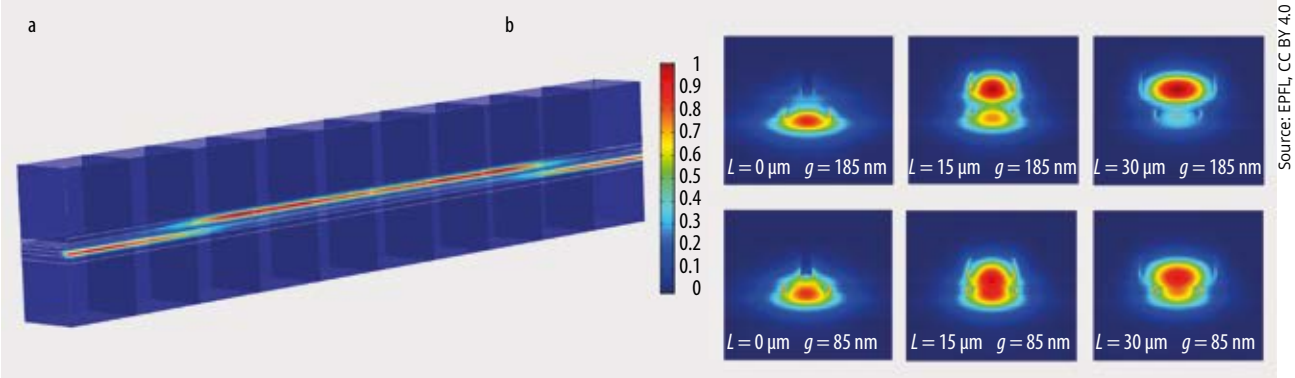

Fig. 3 (a) Light passes from left to right through a path composed of an optical bus and a coupled movable waveguide. (b) The cross-sectional slices of a simulated light waveform as it passes through the coupled device show that the simulation could reveal how that distance affected the speed, or phase, of the optical signal by adjusting the distance between the two optical elements.

Along with determining the physical forms of the waveguide and actuation mechanism, simulation also enabled Sattari to study stress effects, such as unwanted deformation or displacement caused by repeated operation. Every decision about the design is based on the simulated results.

Adding to the foundation

The goal of this project was to demonstrate how MEMS phase shifters could be produced with existing fabrication capabilities. The result is a robust and reliable design that is achievable with existing surface micromachined manufacturing processes, and occupies a total footprint of just 60 µm × 44 µm. Now that they have an established proof of concept, Sattari and his colleagues look forward to seeing their designs integrated into the world's optical data networks. The building blocks created for the future will soon show their potential.

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Text: Alan Petrillo, Content Writer, Comsol

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[1] *H. Sattari* et al.: Optics Express **27** (2019) 18959
[2] *T. J. Seok* et al.: Optica **3** (2016) 64

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Full articles online and in PhotonicsViews issue 5/2022

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

Manufacturers in industries like consumer electronics and optical sensor-based medical diagnostics are seeking new ways to gain competitive advantage.

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. With OpticStudio, UpNano can efficiently design both lens types.

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One software and two lasers for three layers

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

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 joint 'ATSM' project, the Fraunhofer ILT and Eloxalwerk Ludwigsburg Helmut Zerrer (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 (pictured) was the lead project manager.

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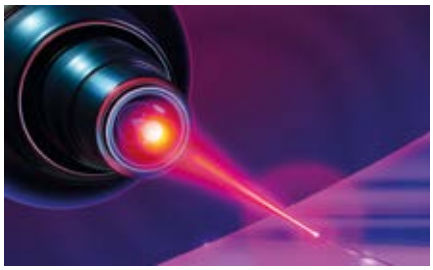
3D beam shaping methods for ultrashort-pulsed laser material processing

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



Ultrashort-pulse (USP) lasers enable microlevel manipulation of material surfaces and work on the bulk of transparent materials with almost no thermal effects. 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.

One of the leading methods of overcoming some of these constraints is beam shaping. This article reviews the concept of 3D diffractive light shaping for USP lasers and show its usefulness in various industrial USP laser applications.

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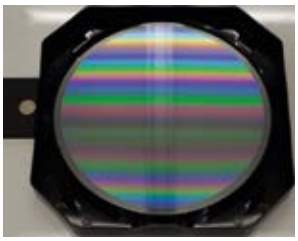
Optical metasurfaces made by cell projection lithography

Electron beam nanopatterning with high optical quality on large areas

Metasurfaces offer promising possibilities for emerging photonic applications like see-through, near-eye displays. Lithography methods are usually the means of choice to pattern metasurfaces, 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 e-beam lithography.



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Fixed focal length or telecentric lens?

The perspective decides – concept and advantages of telecentric lenses

Boris Lange

Source all images: Edmund Optics

In optical metrology applications, telecentric lenses – in contrast to fixed focal length lenses – have the advantage that they provide correct measurement results even when the distance to the object varies.

How do telecentric lenses work? And how exactly do they differ from fixed focal length lenses? This article introduces the peculiarities and explains why telecentric models are predominantly used in optical metrology.

Similar to human vision, fixed focal length lenses (also referred to as entocentric lenses) have an angular field of view, resulting in objects further away being imaged smaller and vice versa. In a metrology setup, this property is undesirable because the measurement result, e.g. the diameter of a component, is not meant to change even if the test specimen is not positioned exactly but only within a certain tolerance range in front of the test system. In optical terminology, this phenomenon is referred to as parallax or perspective error, meaning the change in magnification depending on the working distance. In telecentric lenses, this undesirable property is eliminated or greatly reduced by their design. Fig. 1 shows two identical objects at different distances from the respective measurement setup. The left image shows the scene taken with a fixed focal length lens, for the right image a telecentric lens was used. Despite the significantly different distance of the two cubes from the lens, they are shown the same size in the right image. This visualization is achieved by ensuring that the chief ray runs parallel to the optical axis in the design of the lens. This is the defining characteris-

Company

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Edmund Optics ('EO') is a leading supplier of optics, imaging, and photonics technology for the life sciences, biomedical, semiconductor, R&D, and security markets around the globe. EO designs and manufactures a wide array of multi-element lenses, lens coatings, imaging systems, and optomechanical equipment, while supporting OEM applications with volume production of both stock and custom products. EO's state-of-the-art manufacturing capabilities, combined with its global distribution network, has earned it the position of the world's largest supplier of off-the-shelf optical components.

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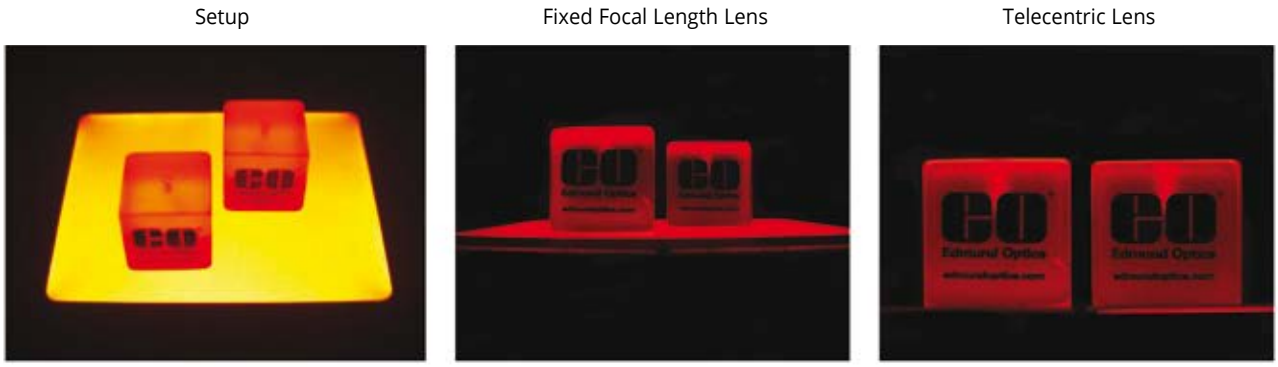

Fig. 1 Middle image: Due to the aperture angle of the fixed focal length lens, the right cube is imaged smaller than the cube of the same size that is closer to the inspection system. Right image: The same scene taken with a telecentric lens. Now both cubes are the same size.

tic of an object space telecentric lens. However, this also means that at least the first lens element must be at least as large in diameter as the workpiece itself to be inspected.

Depth of field

It is often mistakenly assumed that telecentric lenses have a greater depth of field than fixed focal length lenses. Ultimately, however, the depth of field is determined by the *f*-number of a lens; telecentricity only has an indirect impact. The *f*/# is, among other things, decisive for the diameter of the lens. This diameter is anyway large with telecentric optics compared to a fixed focal length lens, all other parameters being equal. Therefore, it is common for telecentric lenses to start only at *f*-numbers of about *f*/6. This is to reduce the diameter, design complexity, but also the cost of a telecentric lens. Fixed focal length lenses can often be opened up to *f*/1.4 – which is unattainable for telecentric lenses.

It should also be noted that when comparing the *f*-numbers of telecentric and entocentric lenses, it is easy to confuse two different parameters. For fixed focal length lenses, the value usually engraved on the lenses denotes the image space f-number for infinite working distance. The choice of this working distance makes sense for several reasons, a quite pragmatic one being that fixed focal length lenses can be used over a large range of working distances and there is no other 'universal' working distance that is applicable to all lenses regardless of focal length or manufacturer. For telecentric optics, however, this choice does not make sense; after all, the working distance is finite and fixed for these lenses. Accordingly, in order to ensure comparability, a parameter known as working f-number is used. It is calculated by weighting the theoretical *f*-number based on infinity with a factor that depends on the specific magnification of the respective lens. For a correct comparison with the f-number of a fixed focal length lens, the value engraved on this lens must be converted by the same factor.

There is another interesting property of telecentric lenses that can give them advantages over entocentric optics in some applications. Due to the lack of perspective, objects become uniformly blurred when you reach or go beyond the limits of depth of field.

If you look at a round object with telecentric optics and leave the focus area, the object will become symmetrically blurred. An algorithm can therefore still determine the correct position of the center of mass. With fixed focal length lenses, the object would be distorted asymmetrically into an ellipse depending on its position in the image, and it would not be possible to determine its exact position. In this respect, it is possible to extend the nominal depth of field in special situations without necessarily having to accept losses in the quality of measurement results. Depending on the application and algorithm, it may even be advantageous to work with a certain amount of blurring. If the transition of an edge is distributed over several pixels instead of only two in the extreme case, a measurement system may provide more repeatable results.

Telecentricity – quantitatively

How is telecentricity quantified? In the data sheets, telecentricity is often specified as an angle, usually together with a wavelength. This angle describes the

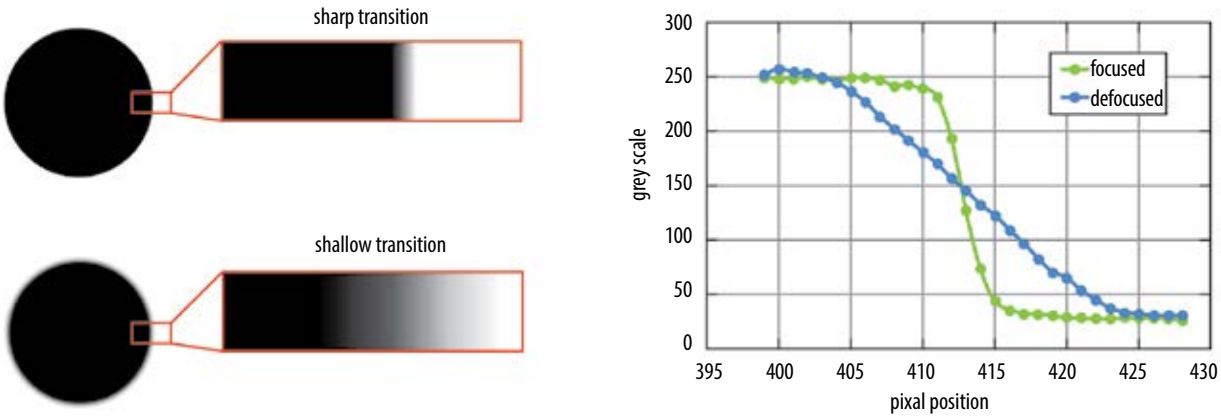

Fig. 2 Left: Image of a round object, once in focus, once with slight defocus. With telecentric lenses, the effect is symmetrical – the position of the center of mass does not change. Right: Line-Out of the two objects. In the defocused case, the edge is distributed over several pixels, which can lead to more repeatable results.

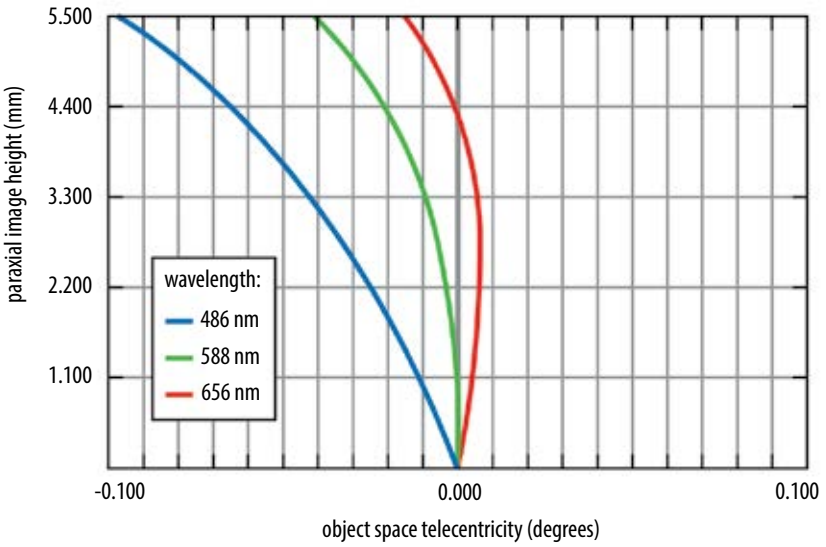

Fig. 3 Typical course of telecentricity (residual angle of the chief ray in degrees) vs. image height, using a 1× lens as an example.

residual angle of the object space chief ray. Since the ideal target is 0°, these are usually very small angles, say in the range of < 0.1°. An exact 0° angle is usually never achieved, because the angle ultimately depends on the wavelength of the light and most lenses are designed for an entire range of wavelengths, not just a single wavelength. It is therefore necessary to find the best possible compromise between the residual angle and the desired wavelength range at which the lens is to be used. Fig. 2 shows an example of data of a telecentric 1× lens where the angle of the chief ray relative to the optical axis is shown for three different wavelengths. The y-axis demonstrates the position of the chief ray on the sensor. By definition, the angle at the center of the image is 0° – here is where the chief ray coincides with the optical axis. When moving from here towards the image corner, the chief ray angle is in most cases described by a monotonic function – i.e. the further away from the image center, the larger the angle. In the example, the angle at 5.5 mm (corresponding to a sensor with 11 mm diagonal, 2/3" format) reaches a value of ~0.1° for blue light of wavelength 486 nm. However, the function does not always have to be monotonic and may differ, especially for other wavelengths. For red light (656 nm), the angle at 5.5 mm is only about 0.015°, and the curve even shows a sign change. At approximately 4.4 mm image height, the angle is 0° again. As a rule, it is therefore advisable to use a graph of this type instead of referring to a single value in a spec sheet, which may not be representative of the parameters relevant to the application. Furthermore, it is recommended to recalibrate an optical measuring system when working monochromatically and changing the wavelength of the light.

Summary

This article presents the applicational advantages as well as the functionality of object space telecentric lenses. Finally, it should be noted that image space telecentric lenses can also offer benefits. These are less sensitive to the exact position and location of the sensor in the camera. Furthermore, the radiometric effect described in the $\cos^4$ law is avoided: the intensity of the light will decrease from the center away to the image edge with the factor $\cos^4$(CRA), where CRA stands for the image space chief ray angle. For a telecentric lens, this angle is 0°, so the factor is 1. Provided that the lens does not have mechanical vignetting in conjunction with the sensor used, no apparent drop in relative illumination will therefore be observed. A final advantage of image space telecentrics kicks in when using precise optical filters installed between the lens and the camera. These filters are usually designed for an angle of incidence of 0°. The more one deviates from this angle, the more the filter response shifts to shorter wavelengths. The filter transmission would thus not be uniform over the sensor area, which is usually not acceptable for precise measurements in e.g. fluorescence or hyperspectral imaging.

In the field of optical metrology, the factor of the lower sensitivity to the exact sensor position is usually the most important. However, in order to achieve the best possible measurement results, it is recommended to use bi-telecentric lenses, which combine the advantages of both concepts.

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Laserpore: a new machine technology for additive manufacturing of porous glass

An innovative solution developed by Ernst Abbe University, Leipzig University, ITG Wismar, and Pulsar Photonics

Source all images: EAH Jena

In the cooperative 'Laserpore' project, an innovative process has been developed for the first time worldwide that allows the generation of porous glass moldings which, on the one hand, have a complex and flexible geometric shape and, on the other hand, a hierarchical pore structure.

▲ A cooperation project to develop an innovative, laser-assisted process to generate porous glass molds

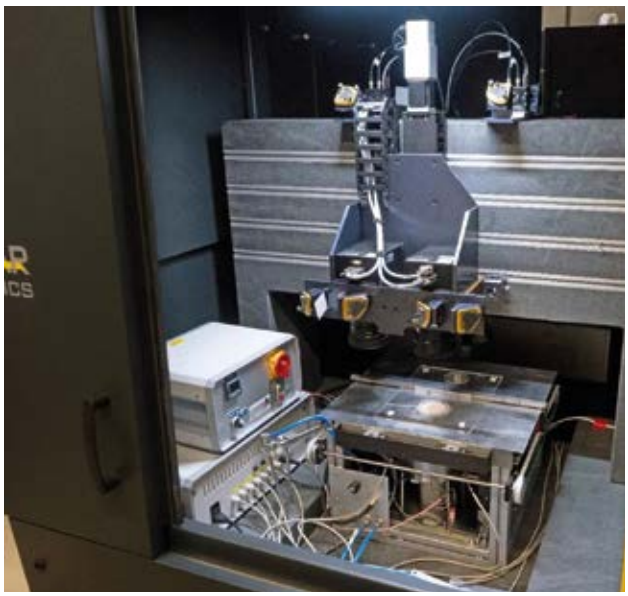
The four project partners from academia and industry have combined the technology of selective laser sintering (SLS) and selective leaching of segregated glasses. The entire process chain from material development, process and equipment development to the production of graduated porous gas structures was considered and investigated by the project partners.

The starting point of the process chain was the product development of novel sensory devices by ITG GmbH, which included their conceptual design and construction as well as the characterization and optimization of sensor-specific porous structures. The University of Leipzig studied the fundamental technical material characteristics of suitable segregable base glasses and their thermal and chemical treatment, which were essential for the successful implementation of the project. The EAH Jena developed a selective laser beam sintering process using ultrashort-pulsed laser radiation.

The laser technology company Pulsar Photonics developed a machine and software-based solution based on the RDX1000 laser machine to produce porous glass molds for application as filter elements. This innovation made it possible to produce sample components as well as component series, and also to shorten the laser processing to a few minutes.

maximum component volume:
D 50 mm × H 150 mm
minimum layer thickness:
≤50 µm
build-up rates per layer:
10 mm³/min to >100 mm³/min

Pulsar Photonics also developed the Photonics Elementes (PE) machine software for laser micromachining applications. PE has specialized software functions for layer-by-layer process control with scanner and axis systems and uses a library of integrated laser beam sources. Laser jobs can be easily parameterized using a solid model or 2D geometry. The sequence and state control of the process is stored in a software recipe and can fur-



Above left: The RDX1000 laser machine for selective laser sintering (SLS) for the production of porous glass moldings developed within the scope of 'Laser-pore'. Right: Kick-off meeting at ITG Wismar (l. t. r.) Dr Stefan Nißen and Uwe Kirsch (ITG), Prof Dr Dirk Enke (U Leipzig), Anne-Marie Layher (EAH), Dr Ingo Knepper (ITG), Dr Jens Holtkamp (Pulsar Photonics), Dr Andrea Barz (EAH), Prof Dr Jens Bliedtner (EAH), Dr Kerstin Wex (ITG)

ther reduce the complexity, depending on the user level.

The further development of the process chamber enables additive manufacturing under defined environmental conditions. A high-temperature furnace was developed for this purpose that prevents premature segregation and thermally induced stresses in the glass mold. Slow cooling, which is achieved by preheating, allows the components to be released from the building platform without causing damage.

At the push of a button, glass molds can be produced with appropriately defined process parameters. These can be produced with different densities and cavities in the millimeter to micrometer range, depending on the material used, the process conditions and the setting parameters. A downstream VYCOR process enables further processing of the components, which was further developed by the University of Leipzig especially for the SLS process. The porous glass components can be used, for example, in the filter systems of ITG Wismar.

Dr Joachim Ryll, founder and managing director at Pulsar Photonics explains: "The entire manufacturing process is based on a layer-by-layer construction of the glass molds and works similarly to 3D printing of metal components. This allows several components to be built up simultaneously in one batch and complex internal structures and surfaces to be created. What makes our solution unique is a high-temperature oven integrated into the laser machine, which enables stress-free 3D printing of porous glass molds."

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Institute

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 the field of laser material processing are the research of basics in laser beam interactions, the development of special processing methods and the solving of industrial applications.

www.eah-jena.de/scitec

Company

Pulsar Photonics

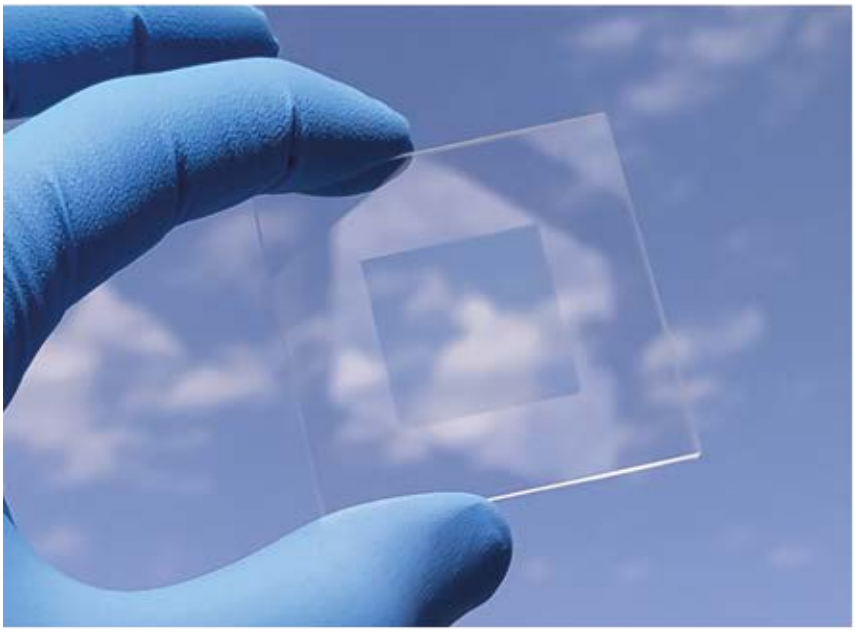
The range of services of this high-tech company includes the development, production and distribution of laser machines for material processing with short and ultrashort-pulse lasers. A second core competence of the company is the integration of tooling and measuring systems for material processing, adapted to the specific requirements of the application. Besides its expertise in system development, Pulsar Photonics is also a competent partner for single-part and series production with (ultra)short-pulse lasers. Its core focus is on structuring, drilling and precision cutting. Founded in 2013, Pulsar Photonics GmbH is one of the fastest growing companies in Europe, according to the Financial Times and Statista. Pulsar Photonics has been part of the Schunk Group since 2021.

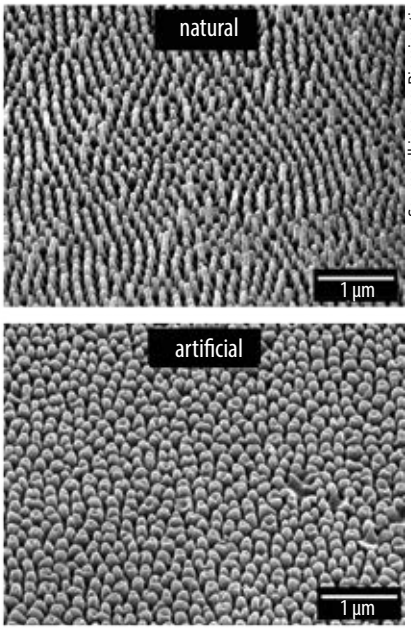
www.pulsar-photonics.de

Multifunctional laser-induced nanostructuring of glass

Latest technological advances on selective glass surface processing with ultrafast laser light for antireflection, antiglare and antifogging properties

Evangelos Skoulas, Alexandros Mimidis, Antonis Papadopoulos, Andreas Lemonis, and Emmanuel Stratakis





Source all images: Biomimetic

A comprehensive report is provided here on a single-step approach to the selective surface processing and functionalization of glass components with laser pulses. In particular, it is shown that biomimetic, self-organized, deep-subwavelength, quasi-periodic nanopillar structures can be realized using ultrashort laser light. These structures have an enormous effect on the properties of the glass, including optical and wetting. Remarkable antireflection and enhanced transmission, tunable glare as well as a strong antifogging effect of the laser processed glass are shown. Several use cases are discussed for selective glass surface functionalization, including optical fiber tips and curved optical lenses.

Glass has been used for thousands of years due to its chemical inertness, hardness and profound optical clarity. It finds applications that span from architectural use to specialized optical components and protective covers of electronic devices and screens. Due to its unique combination of properties and the perpetually increasing requirements of smart devices, glass is still one of the most important and popular materials of the modern age. Current technological progress drives a constant need for novel and innovative glassy materials that possess engineered properties beyond the conventional attributes of glass. In order to tailor the glass properties for every application that the industrial trends dictate, several processing and treatment methods as well as new chemical compositions have been developed. Forming, surface coating, thermal tempering, annealing and chemical strengthening, to name a few, are some of the most common methods of enhancing the desired properties of glass. One of the most interesting ways towards glass functionalization is surface engineering. This essentially involves the reshaping of the surface into functional structures that induce novel or augment existing properties. Some prominent examples are increased transparency, greatly suppressed reflection, antifouling, and extreme wettability and fluid transport.

▲ **Fig. 1** A SiO_2 glass treated in the middle with laser nanotexturing (left), tilted SEM images of the nanostructures of an actual cicada wing (top right) and the glass surface (bottom right).

Here we report on a new method which has proven to be a precise and highly versatile tool to realize nanotex-

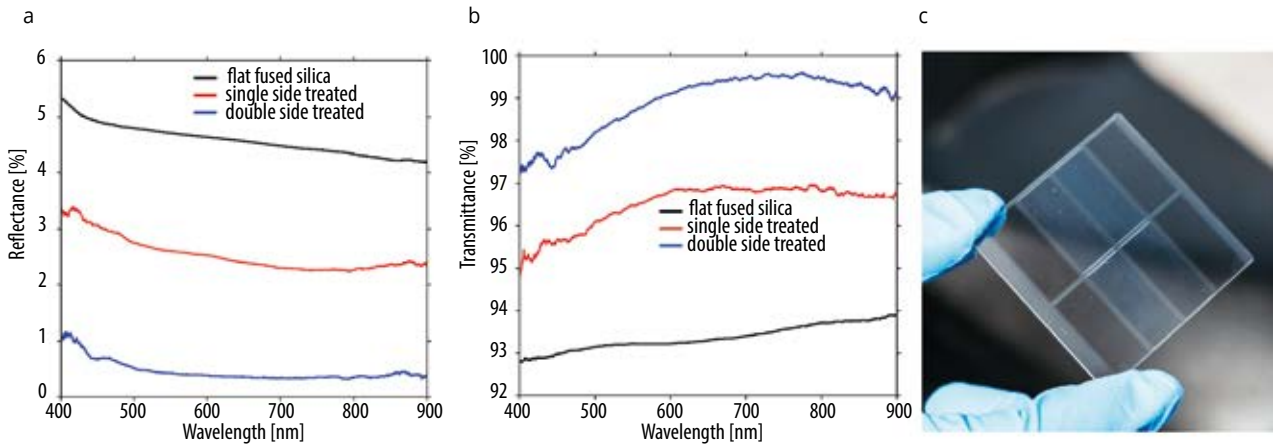


Fig. 2 Reflectance (a) and transmittance (b) measurements for flat SiO_2 glass (black line), single side nanotextured (red line) and double side textured (blue line), (c) photograph of different surface treatments with variable haze values.

tured glass surfaces which, due to their morphological features and functionality, demonstrate unique applicability for antireflection (AR), antiglare (AG), and antifogging (AF) applications [1]. Furthermore, preliminary results indicate that the AR treatment exhibits almost twice the damage threshold of the bare glass. Glass structuring using ultrashort (less than 1 ps) laser pulses, is a maskless process allowing material modification via laser scanning in an ambient environment. This occurs through transient matter phase transition and material self-assembly taking place at the nanoscale. These complex, self-organized features upon resolidification permanently reshape the material surface [2]. The nanostructures are directly imprinted on the glass surface by laser scanning across any selected area. Size, orientation, periodicity and shape of the features can be tailored through careful manipulation of the beam properties as well as the scanning conditions [3].

The concept of biomimetic surfaces has developed from the underlying principles discovered in natural surfaces like butterfly wings and the eyes of moths [4], opening new opportunities for innovation and exploitation in materials science and engineering. Due to the diversity of biomimetic surface functionalities, inspirations from natural surfaces are interesting for a broad range of applications in engineering, including phenomena of adhesion, friction, wear, lubrication, wetting phenomena, self-cleaning, antifouling, antibacterial phenomena, thermoregulation and optics. Lasers are increasingly proving to be promising tools for the precise and controlled structuring of materials at micro- and nano-scales. When ultrashort-pulsed lasers are used, the optimal interplay between laser and material parameters enables structuring down to the nanometer scale. Besides this, a unique aspect of laser processing technology is the possibility for material modifications at multiple (hierarchical) scales. Inspiration is drawn from natural archetypes to design technical functional textures. The process we demonstrate is inspired by the cicada wings and offers a reliable and easy method to fabricate biomimetic, multifunctional glass surfaces. Several use cases are discussed, as well as current development towards effective wavelength control with deep nanostructuring, the treatment of optical fiber tips and the texturing of curved optics.

AR and AG glass nanotexturing

AR performance has been achieved via laser scanning onto the glass while it sits on a holder with galvo scanners and high-power, repeatable laser systems. The geometric features of the nanostructures along with their nanometric size create a gradient material volume. Incident light therefore encounters a refractive index gradient as it propagates from sparse to denser space. This effect is realized by the effective medium theory (EMT). Given that the period of the nanostructures is within the range of tens to a few hundreds of nm, it can be efficiently utilized for visible light. The maximum area that can be treated with the current method is 24 cm × 24 cm, but using proper adjustments however, the processing area can be effectively limitless.

Direct laser nanotexturing for AR treatment has already been tested for fused silica (SiO_2), aluminosilicate, borosilicate, soda-lime silicate, sapphire and some kinds of float glass. The glass thickness is irrelevant for thicknesses >1 mm and the surface quality (scratch and dig) does not hinder the process. The laser processing conditions are the key parameters for processing different types of glass and have a significant effect on the morphological fea-

Wavelength	LID-max nanotextured AR (J/cm²)	LID-max bare substrate (J/cm²)
355 nm	41.7	27.1
532 nm	97.9	49.2

Table 1 LID-max was calculated for the energy density from which surface damage is always observed for AR treated and bare fused silica glass substrates.

Company

Biomimetic

Nature's ingenuity in surface engineering – Biomimetic's mission is to enhance raw material surfaces with extraordinary functionalities. It offers bioinspired laser nanotexturing of glass that has an optimal combination of antireflective, antiglare, antifogging, and superhydrophilic properties. Unlike other nanotexturing technologies, Biomimetic's technology relies on a green, push-button process, minimizing the need for chemicals and consumables.

www.biomimetic.gr

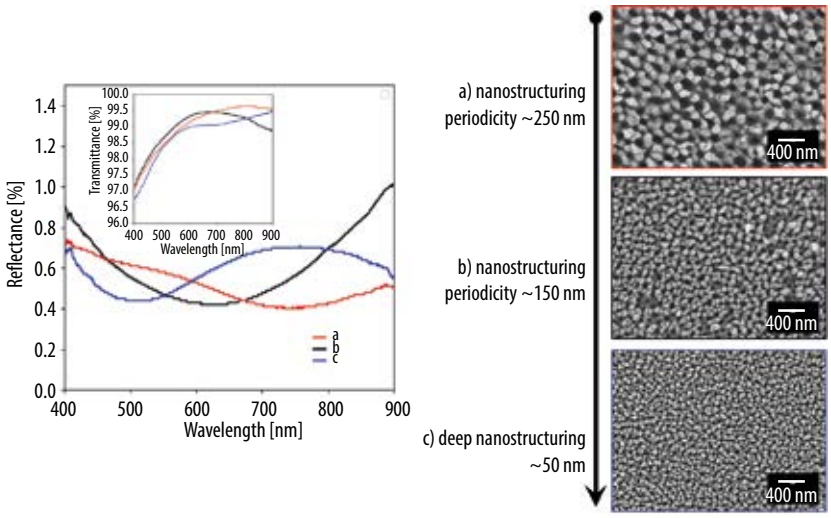


Fig. 3 Reflectance values vs wavelength (left) for (a), (b) and (c) nanotextured surface cases with the corresponding SEM image (right) from hundreds of nanometers in periodicity to deep nanotexturing.

tures of the final nanotextured surface. Fig. 2 shows the reflectance and transmittance measurements for the visible and near-infrared spectrum of a piece of typical fused silica glass (25 cm^2) when processed on a single side and both sides with respect to the bare substrate. Besides that, within the overall process it is possible to control the haze of the final product from values <1 up to >20, attributing AG effects upon request.

Another important aspect of this surface processing method is that the final surface characteristics can exhibit a damage threshold almost twice as high as the initial glass substrate. So far it has already been tested for 355 nm and 532 nm wavelengths for a ~2 ns pulse duration. The laser induced damage (LID) was calculated as the energy density from which surface damage is always observed and was classified as LID-max. The respected fluence values for treated AR and non-treated fused silica substrates are shown in Table 1, indicating that the product can be suitable for high power applications.

Towards effective wavelength selection

In the special case of optical components where single wavelength applications are dominant, AR technologies usually offer solutions designed for particular narrowband wavelength ranges. Comparing this new method with traditional and well-established technology, a significant challenge in the tuning of a respective property at specific wavelengths was always the most limiting factor. The ability to consistently, precisely and rapidly fabricate spatially variable nanometric features can result in tuning the effectiveness of the AR surface at specific wavelengths. Fig. 3 presents the latest advancements in an effort to control the AR effective wavelength by an increase or decrease of the surface feature periodicity. The three SEM images with blue, black and red frames correspond to the same-colored lines highlighted in the reflectance and transmittance diagram. Ranging from a few hundreds of nanometers to deep nanotexturing with a period of ~50 nm, and even lower in some cases, this is a demonstration of the AR tunability of laser-induced nanotexturing technology.

Optical fiber tips

The ability to selectively nanotexture almost any type of glass component can be of huge importance for use cases such as optical fiber tips. This is a strategy employed when light losses during fiber-to-fiber coupling must be eliminated. It is now possible to selectively treat just the core, or even the core with some selected areas of the cladding, directly on the tip of an optical fiber. Fig. 4 illustrates a multimode (OM3) optical fiber as an example. It is possible to successfully process from one single-mode fiber tip up to hundreds for faster production, as the most limiting factor can be sample positioning time or bundling multiple fiber tips. The resolution or the smallest processing areas that can be achieved with this method are limited by the focusing optics and the laser beam diffraction limit. Nanotextured fiber tips exhibited reduced reflectance, similar to the values presented in Fig. 2. These results indicate that the method can be suitable for any type of fiber tips, either used for high power applications, i.e. laser to fiber coupling, or for spectroscopy and fiber sensing. Furthermore, direct laser nanotexturing has been successfully applied to curved lenses, plano and biconvex. In this case, either the lens or the laser beam are moving while the focus is adjusted.

AF glass nanotexturing

Glass is an inherently hydrophilic material, and when it is wetted, water tends to make droplets that cover its surface. This relative affinity for water is evident in contact angle measurements. Fig. 5 (red frame), illustrates a drop of water that sits on a flat fused silica following a sessile-drop contact angle test. Nano-

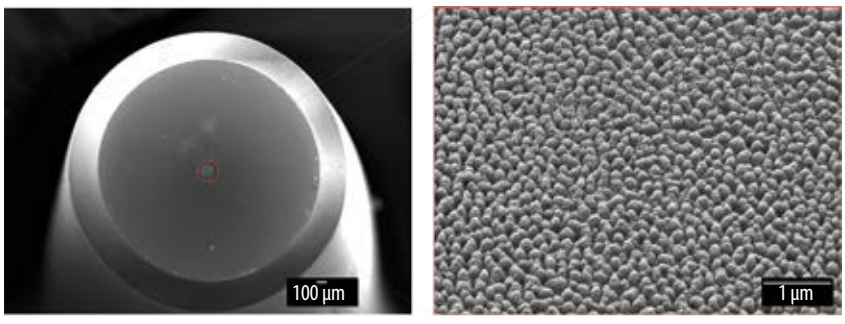


Fig. 4 (left) Top view SEM image of an optical fiber tip treated only in the core – red dashed circle. (right) SEM higher magnification of the nanotextured fiber core.

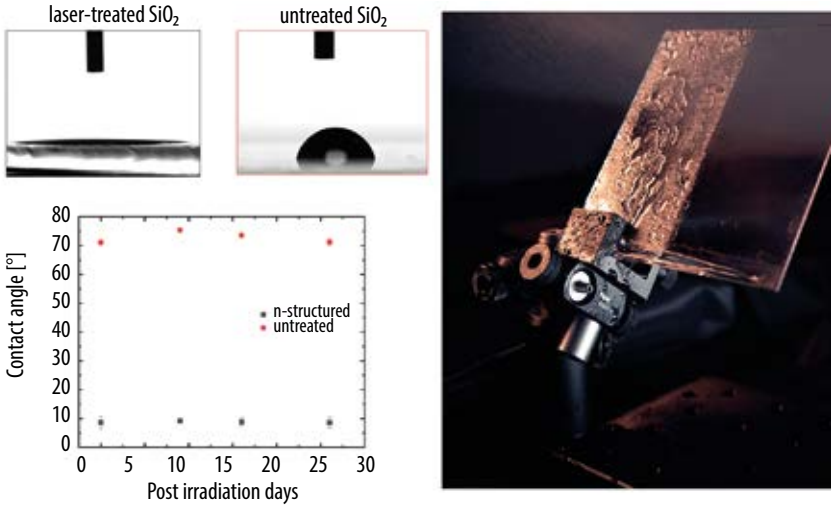


Fig. 5 Contact angle images of nanotextured (black frame) and non-textured (red frame) glass

texturing of glass roughens its surface, which dramatically enhances its affinity to water, while the optical properties are either the same or improved. This is reflected in Fig. 5 (black frame) where a water droplet completely spread once it was placed on a nanotextured fused silica area. Intriguingly, this effect is stable for more than a month. This is schematically presented in Fig. 5 (bottom left) where repeated contact angle measurements were taken every few days for one month. This demonstrates that textured surfaces become and remain strongly hydrophilic compared to the untextured glass. Strong hydrophilicity is useful in antifogging applications where water condensation, mist or precipitation distorts vision. By augmenting glass hydrophilicity, the water spreads evenly and forms a thin film that does not obstruct vision. This applicability is demonstrated in Fig. 5 (right) where a half-textured glass piece is placed on a holder and water is sprayed onto it. The untreated surface on the left is covered in water which forms droplets and blocks vision. In contrast, the water completely spreads and allows clear vision on the right-hand nanotextured region.

We have demonstrated a reliable, single-step method to manipulate glass properties for antireflection/antiglare and antifogging applications. We envisage that the novel, laser-based, biomimetic fabrication on transparent dielectrics presented here will have a huge impact on relevant applications, considering the simplicity of the process coupled with the high damage threshold of the antireflective structures attained. Antireflective transparent materials can be useful for a wide range of technological applications including everyday electronic device screens, solar windows, optoelectronic device covers and optical components. Demand for glass as well as for new and greener processing techniques is therefore expected to increase.

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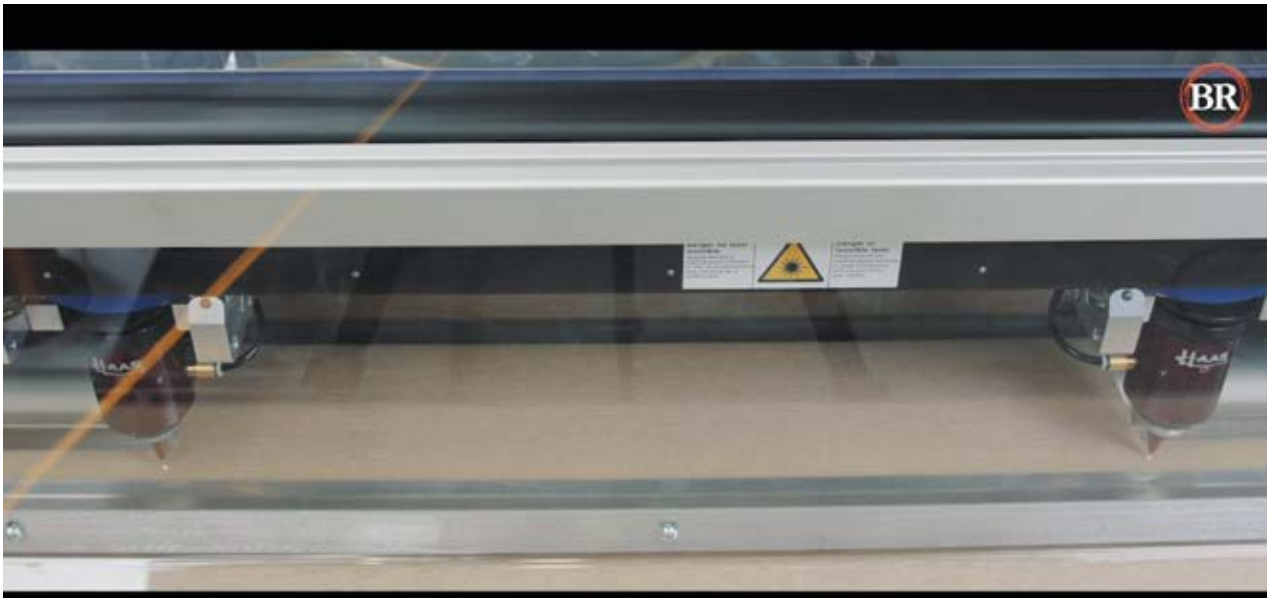
Electrifying lasers for the transformer industry

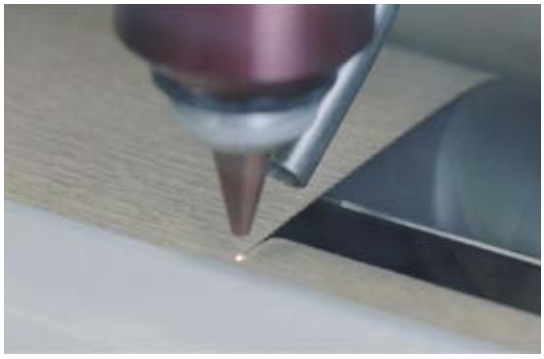
How CO_2 laser sources are being used for paper cutting



Laser cutting crepe paper with a SR 15i CO_2 laser source from Luxinar (Source: BR Technologies)

BR Technologies is enabling a transformer manufacturer to cut its insulation paper in a unique way by using lasers integrated into its machines. The SR 15i CO_2 laser sources from Luxinar are cutting crepe paper, which is used as an insulation layer inside the electrical transformers that are sold to power grid suppliers.

The uniqueness of this application is twofold: first, insulation in most power transformers is made from oil and cellulose (paper/pressboard), not crepe paper, and second, these materials are usually cut mechanically using blades, not by laser. Additional requirements were for the laser system to automate a process that had previously been done by hand, and that it should produce a clean cutting edge.



Close-up of laser cutting crepe paper for the electrical transformer industry (Source: BR Technologies)

Tobias Beitz, sales manager at special machinery manufacturer BR Technologies, describes the importance of a precise cut as follows: "Having a clean cutting edge was one of the biggest challenges we have faced. When cutting crepe paper with a laser you inevitably get a slightly burned edge. Each little bit of the burned material does contaminate the oil in which the coil is immersed when the transformer is assembled. This can cause faults in the transformer after a while, which can be devastating to the transformer manufacturer."

"Getting a perfect cut is almost impossible, since there is some variance in the thickness of the crepe paper and it is impossible to always hit the sweet spot of the laser. However, with the help of Luxinar support we managed to get the cutting edge so clean that only in direct comparison a slight browning may be visible. This has proven to be good enough in tests with the transformer oil."

"We made some preliminary studies with a German research institute to determine the composition of the generated dust and to determine the long-term health effect this might have on the people working in the vicinity of the machine as it turns out burned paper is toxic and needs to be filtered and sucked away. Therefore a central suction system was installed that filters and sucks away the dust from both our machines and leads it directly outside the factory."

BR Technologies has integrated a laser in its equipment using a beam splitter to mark both sides of the crepe paper at the same time

Beitz explains why Luxinar's CO_2 laser sources were chosen for this process: "Usually the coil winding process is adjusted to the machine's capabilities. However, in this specific case the customer needed to keep the transformer design as it is, but still wanted to automate the manufacturing process as much as possible. This required a cutting system that can cut the crepe paper into any shape. After some research we found that a laser system is the only viable solution for this. It might be more expensive than the regular cutting blades that are usually used, but the possibilities that this system enables more than make up for it in our case. In the end this allowed us to fully automate the coil winding process from start to finish with no manual intervention. An operator is only required for loading, starting the winding process and unloading the finished coil. This way, only one operator is required to easily operate two of our machines." He goes on to describe how the lasers are integrated in BR Technologies' equipment, "The laser itself is mounted on the machine frame in a fixed position. Since the crepe paper can move in any direction, we needed a way to direct the laser to any position in the machine. For this we used two tubes that connect the moving part of the machine with the fixed part and mirrors that precisely direct the laser through the tubes. A beam splitter is used to split the beam into two separate beams. This allows us to use the same laser to cut the left and right side of the crepe paper at the same time."

The SR 15i is from Luxinar's well-established SR series of sealed CO_2 laser sources with powers of up to 250 watts and an IP66 rating to ensure a high level of protection against dust and water ingress. The laser is based on a diffusion-cooled slab principle that gives a high-quality, round, and symmetrical beam and, in addition to cutting, the SR series is used for drilling, engraving, marking, perforating, scribing and welding in a variety of industries. The two SR 15i lasers installed in BR Technologies' machines are making approximately fifty short clean cuts per crepe paper coil on a production line that is operating at speeds of around fifty millimeters per second.

Luxinar offers a versatile laser source portfolio that caters for a diverse range of industries, including automotive manufacturing, electronics, fashion, food and beverage, packaging, glass, medical and pharmaceutical. The company's industrially-proven OEM, SCX, SR and SR AOM sealed CO_2 laser sources are available with power levels up to 1 kW at three different wavelengths (10.6, 10.25, and 9.3 µm), allowing solutions to be tailored to customers' specific needs. The Luxinar MULTISCAN laser marking systems offer an inkless method to apply text, graphics and barcodes to a wide range of materials and the LXR series represents the company's first range of femtosecond laser sources. This Luxinar-patented technology has revolutionized materials processing due to its large dynamic range of average powers (up to 120 W), pulse energies (up to 100 µJ) and pulse repetition frequencies (single-shot 40 MHz) and it has target applications in the electronics, medical device, printing, security and automotive industries.

BR Technologies has been supplying high-quality winding equipment since 1948 and is a market leader in the transformer winding industry with innovative new projects and research focusing on increasing the automation of the machine to increase the quality, production time and efficiency of the product. They chose Luxinar because "… it had the right specifications, a good price and was close enough to us in Germany. Since this is our first laser, we wanted to have a supplier close by in case we need support. And it paid off. Without the support of Luxinar we would have taken months longer to get the process running as smoothly as it does now."

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Company

Luxinar

At Luxinar, we have a singular focus: developing laser technology to enhance our world.
Like a laser that channels light into a single, powerful beam, we focus on improving the lives of our customers. This allows us to create solutions to meet every single challenge – from heavy industry to delicate, high precision applications.
Luxinar has been at the forefront of laser technology for over twenty years and is a leading manufacturer of sealed carbon dioxide laser sources up to 1000 W and, more recently, femtosecond laser sources. To date, we have an installed base of over 20,000 lasers worldwide in industrial applications environments.

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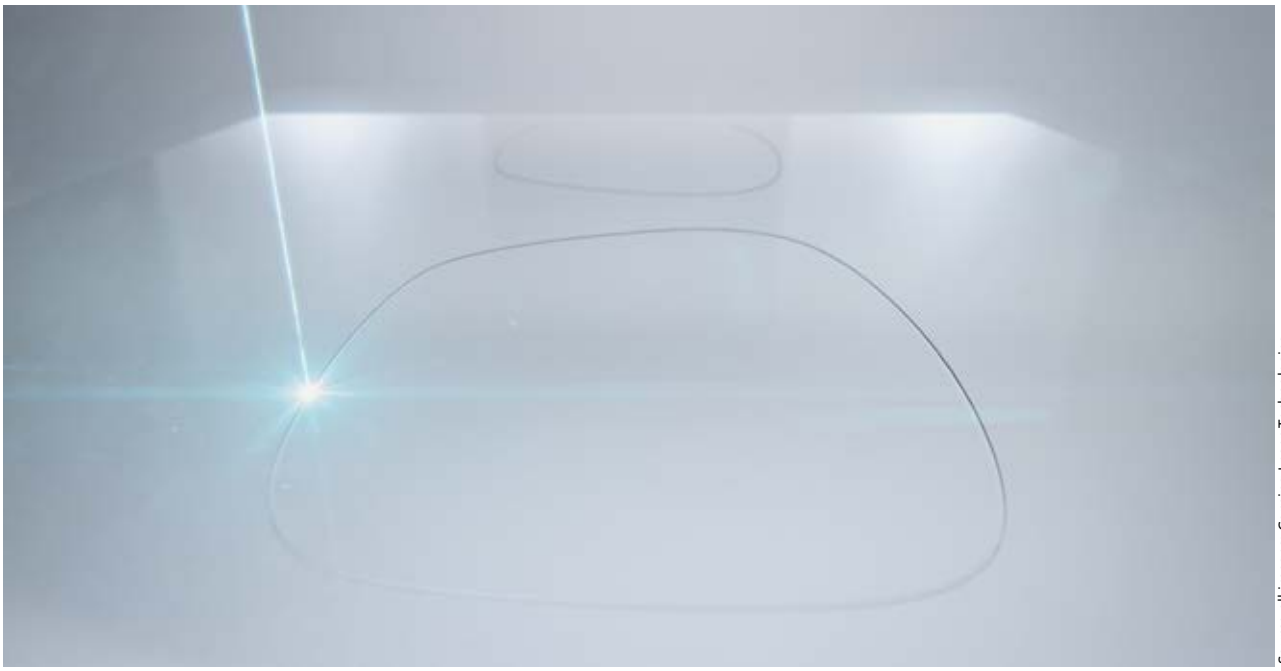
Enhanced edge strength for augmented reality waveguide laser singulation

Edge strength is a key metric to evaluate the performance of a laser cutting process

Andreas Gaab, Tobias Roeder, Quentin Hayet, and Alejandro Becker



Source all images: Corning Laser Technologies

With a new enhanced nanoperforation (EnP) approach, Corning Laser Technologies can demonstrate an increase to 128 MPa B10 in edge strength (ES) for 1.8RI glass. This will help designers and manufacturers to meet the expectations of future AR applications.

Augmented reality (AR) devices are designed to overlay a real-world image with an electronically generated image for human vision. One essential element of AR devices is diffractive waveguide technology that guides light from a projector through the eyepiece into the viewing field of the observer. To extend the field of view and to reduce the weight of the devices, the types of glass used are designed to have a high refractive index that provides the required total reflection inside the waveguide.

The waveguides are used in a human portable device and so the form factor of the devices should be organic and shaped like typical goggles. Besides the shape, also the weight of the devices is important, so cutting close to functional areas (i.e. the imprinted grating that couples the light in and out of the waveguide) is important. These two factors lead to challenging processing requirements for the singulation from a wafer to an individual part, potentially having tight radii and even concave corners as seen in Fig. 1.

To add to this, the value of the processed wafers is high given the high precision of the micro-optical structures on the wafers. This leads to an elevated expectation of the cleanliness, yield and throughput of the process to singulate the parts from the wafers.

Laser cutting has established itself as the method of choice for such parts and the Corning Laser Technologies nanoperforation (nP) process, combined with a thermal laser release process, provides a proven solution for this application.

▲ **Fig. 1** Typical shape for glasses utilized for AR goggles. An introductory Corning video on AR technology can be found at: youtube.com/watch?v=xcaU7kpGjpY

Details of the CLT nP cutting process

Using the CLT laser cutting process for glass, a two-step, laser-based singulation process, is a clean, qualitative and high-speed process for high-index

Fig. 2 Fully automated process solution by CLT to singulate eyepieces from a wafer to a part.

glass compositions. The first step creates a micrometer-scale modification throughout the full thickness of the glass. This modification progresses less than 10 µm into the glass sideways but is strong enough to steer the crack through the glass for rounded contours. The second step is connecting the microcracks generated by the modification process by using a thermal stress that is induced by a second laser process, to a macroscopic crack, and thus enabling the force-free picking of the singulated parts. These processes can be implemented within a standalone, operator-based laser system or, as shown in Fig. 2, within a fully automated processing solution to singulate the eyepieces from a wafer, from a cassette to a tray.

Influences on the separability of wafers

The key properties of the source wafers are determined by their glass composition, which is designed to provide a high refractive index as well as good transparency. The glass composition will also influence the laser processability, as summarized in Table 1.

In addition to these glass properties, the finishing and additional production processes will also influence the ability to use laser cutting on the glass wafers. Beside the surface quality of the wafers, which is typically at an optical grade, additional surface coatings to improve the optical performance of the device need to be mentioned here. As an example, the antireflection coating (ARC) might inhibit the laser process and should be designed to allow later laser singulation. The ARCs supplied by Corning are designed to be compatible with this singulation approach.

Established performance of laser cutting

The requirement for the singulation process of augmented reality glasses is a clean process with a high-quality edge. Since the active layers are already applied onto the wafer prior to the singulation process, no additional finishing processes can be applied after singulation. All the requirements for the singulation process are fulfilled by the CLT cutting process, which provides a homogeneous, non-dangerous, and high-quality edge without any additional edge finishing steps. The typical processable thickness of the glass is currently up to 1.0 mm for the legacy nP and up to 0.6 mm for the EnP.

The CLT cutting process is clean, dry and can be operated in a clean environment, since it does not require any wet finishing process such as grinding or polishing.

Edge performance of laser cutting

A key metric for the edge quality is the edge strength (ES). This performance is measured in a destructive test, described later in greater detail.

The CLT laser cutting technology achieves typical B10 edge strength values of 60 – 90 MPa with different glass compositions from various suppliers. Currently, this performance is within customer expectations and few concerns are voiced on this performance. This might be due to the fact that the current designs of AR devices have the waveguide plates mounted solidly in a frame, making edge strength and impact strength an unimportant factor so far. In future, edge strength will become more and more important and will be a major differentiator for competitive laser singulation technologies and laser process suppliers.

Edge strength measurement background

The test method for edge strength is a destructive test where a force is applied to a glass specimen under bending stress. The maximum force required to break the glass is recorded and, if the break occurred at the edge of the specimen, it is evaluated. If the break occurred on the surface of the glass, the measurement is discarded as it primarily shows the surface quality of the wafer and not the edge performance.

A 4-point bend (4PB) setup with a span width of 36/18 mm is typically used for glasses in the range of 0.4 – 0.7 mm thickness and the Young's modulus of

	1.7 AR	1.8 AR	1.9 AR	2.0 AR
RI	1.70	1.80	1.91	2.0
CTE [ppm / °C]	8	9.1	7.5	8.4
Density [g/cm^3]	3.23	3.65	4	5
Young's modulus [GPa]	91.2	115.8	119.5	127

Table 1: Overview of the PGS-relevant products for AR high refractive index waveguides. Please refer to the current specification sheets for details.

Company

Corning Advanced Optics

We serve the semiconductor and consumer electronic industries by supplying optimized glass compositions with tailored properties in wafer and panel formats. In addition to glass, Corning offers supporting capabilities including laser cutting systems for highly accurate wafer dicing as well as world-class metrology instruments for inspection. Corning enables the fabrication of innovative products by combining unique glass manufacturing and superior processing capabilities to offer total solutions to customers, not only solving various technical challenges from glass supply- to inspection and processing, but also reducing design cycle time and cost.

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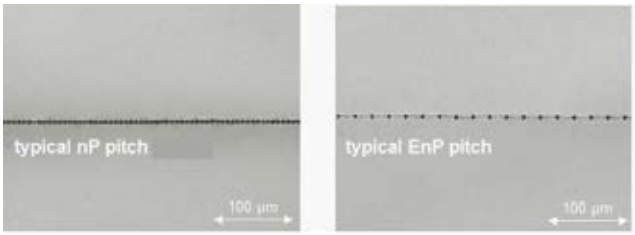

Fig. 3 Typical image of the laser influence on the glass before separation. Legacy nP shown on the left with a smaller pitch, on the right-hand side the EnP process can be applied with a larger pitch. An increased parameter range is addressable by using the EnP, and this can be used, for example, to optimize for better edge strength performance.

the AR glass compositions. The procedure is described in greater detail in ASTMC1161.

A test specimen geometry of 45 × 22 mm is used as the currently utilized wafers mainly have a diameter of 200 mm. Statistically reasonable evaluations of a 4PB test can only be realized when more than thirty samples are measured per evaluation. In order to reduce the data from the failure stress distribution, a Weibull distribution is utilized and the B10 value is typically used to compare datasets. The B10 value means that 10 % of the samples broke with a lower ES value than the B10 stress value. To compare the performance of different test runs or of different singulation techniques, the slope and the confidence intervals of the Weibull distribution also have to be taken into account when comparing ES performance. So it is always helpful to compare full datasets against each other and not to rely only on a single B10 value comparison.

For specific customer requirements, the relevant failure rates to be analyzed will be much lower than the 10 % value, but given the confidence level of the typically used sample quantities, the B10 values are established to reliably compare datasets against each other. Larger datasets are required for lifetime considerations of real products to evaluate B-values at low percentages, and these should be analyzed customer-specifically with the relevant coatings and structure on the glass. Corning can provide support here with more technical background on the theory of glass reliability.

Edge strength improvements by laser cutting utilizing EnP

The 0.6 mm thick Corning 1.8RI 200 mm diameter glass wafers were used for this study. These are established in the AR community for diffractive holographic displays and further details can be found on Corning's Website. The wafers were non-coated or further processed in order to establish a good understanding of the baseline performance. For the ES measurement, rectangular parts must be cut from the wafer and one wafer can be populated with 24 parts. So two to three wafers needed to be used for one data set.

Key drivers of breaking performance and CLT solution for a better ES performance

As discussed, the 4PB test shows what the main drivers are to weaken the break resistance of a glass. Firstly, surface defects must be mentioned here as influences. These can be identified by the appearance of the break and these measurements can be discarded. Secondly, mechanical impacts on the edge can reduce the achievable edge strength and care must be taken during sample handling and shipping. Finally, the performance of the singulation technology will determine the strength of cut parts. This strength is related to the flaws and the sub-surface damage that is introduced into the glass by the cutting technology, and a reduction of these will increase the strength. One key driver for higher ES is to reduce the subsurface damage of the cutting process. From the established laser cutting process, CLT has developed an enhanced laser setup that results in higher ES.

Fig. 3 shows a typical perforation for (left) the legacy nanoperforation as well as (right) the enhanced nanoperforation. The enhanced nanoperforation setup creates a perforation that allows different laser parameter regimes to be used compared to the legacy nanoperforation, especially the pitch of the laser interaction. Those laser parameter regimes result in less subsurface damage and thereby increase the edge strength. The combination of this enhanced setup together with the optimal parametrization of the overall process can lead to unprecedented edge performance for laser singulation and shall be discussed in the following in greater detail.

In addition to the enhanced ES performance, the EnP also provides better contour control and enables tighter radii and more complex outlines compared to standard laser cutting methods.

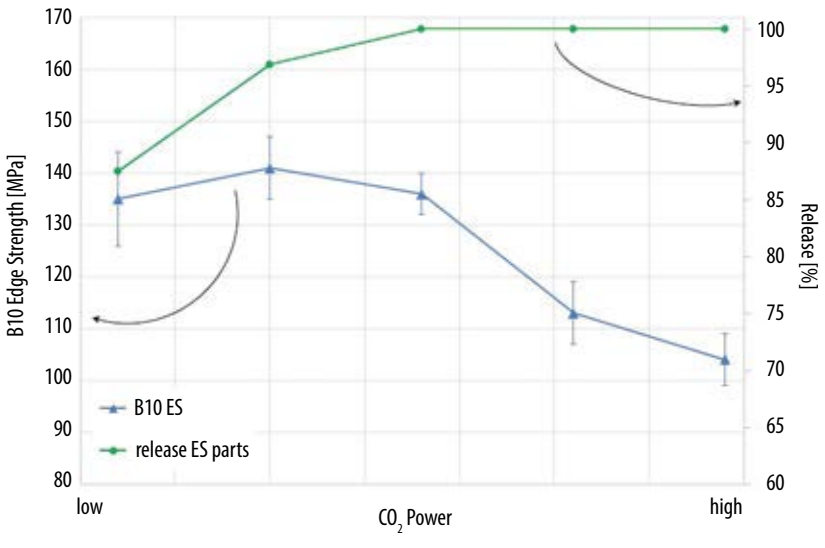

Fig. 4 Influence of the CO_2 laser process on edge strength and part release

Parameter influences on ES performance

As well as the enhanced optical setup to distribute the laser energy into the glass, the parameter settings of the laser processes need to be understood to establish an optimal process. Both laser processes, the enhanced nanoperforation and the CO_2 release, influence the edge strength. The laser parameters must therefore be carefully selected to achieve a robust

CO_2 release, high edge strength and minimal chipping.

Enhanced nanoperforation

The key influences of the EnP laser process on ES are:

- the pulse energy of the modification process
- the intensity of the pulses
- the distance between the perforation dots

A design of experiment (DoE) is performed to identify the best combination between high edge strength and good CO_2 releasability. With the DoE approach, a parameter range is defined and tested with distinct combinations. The evaluation can be visualized using a multidimensional map and the optimum combination of parameter settings for the enhanced nanoperforation can be identified.

CO_2 release process

The key influences of the EnP laser process on ES are:

- the power of the separation process
- the spot size

Fig. 4 presents the influence of the CO_2 release process on edge strength as well as the CO_2 separation process. The full release of the parts is achieved at a CO_2 pulse energy of $E_p \geq 4.5$ mJ. To ensure process stability and a stable release yield, a slightly higher pulse energy ($E_p = 5.2$ mJ) was used for these investigations. The required CO_2 laser pulse energy will change with glass thickness and type, but also with part geometry and part packaging densities on the wafers. Therefore, the achievable edge strength has to be evaluated in detail for each custom design.

CO_2 pulse energies: intermediate power results in a full release (100 %).

This in-depth investigation of the enhanced nanoperforation for Corning 1.8RI glasses will help to find the optimal laser parameters for each customer product in a reliable and fast way.

This baseline performance and parametrization can be used to understand the influences of custom design and production expectation and to find the best fit for the given customer expectation. The key influences to mention here are the custom designs for part size, thickness and shape, part packaging density and orientation on a wafer, coatings and layers for the functionalization of the parts. All of these will influence the achievable performance for throughput and cutting quality of the final products.

Results for edge strength of enhanced nanoperforation

The edge strength achieved in this study proves to be much higher than typical edge strength values achieved for standard nanoperforationThe achieved edge strength of standard nanoperforation using an established parametrization for these types of glass and the optimized enhanced nanoperforation parametrization were evaluated within this study.

Utilizing the Enhanced nanoperforation, the edge strength might be increased from ~70 MPa to 128 ±10 MPa for a comparable product without any change in the product details.

Summary

By utilizing a DoE approach, the influences of the laser parametrization with respect to ES have been investigated for 0.6 mm thick 1.8RI Corning glasses. The EnP method delivers an unprecedented performance of 128 ± 10 MPa; B10 has been established by the full process flow for automated laser singulation. These results show that Enhanced nanoPerforation can increase the ES by over 50 % compared to established laser processing. Besides this benefit in ES increase, this EnP technology also provides unmet performance for contour accuracy and edge surface quality.

*

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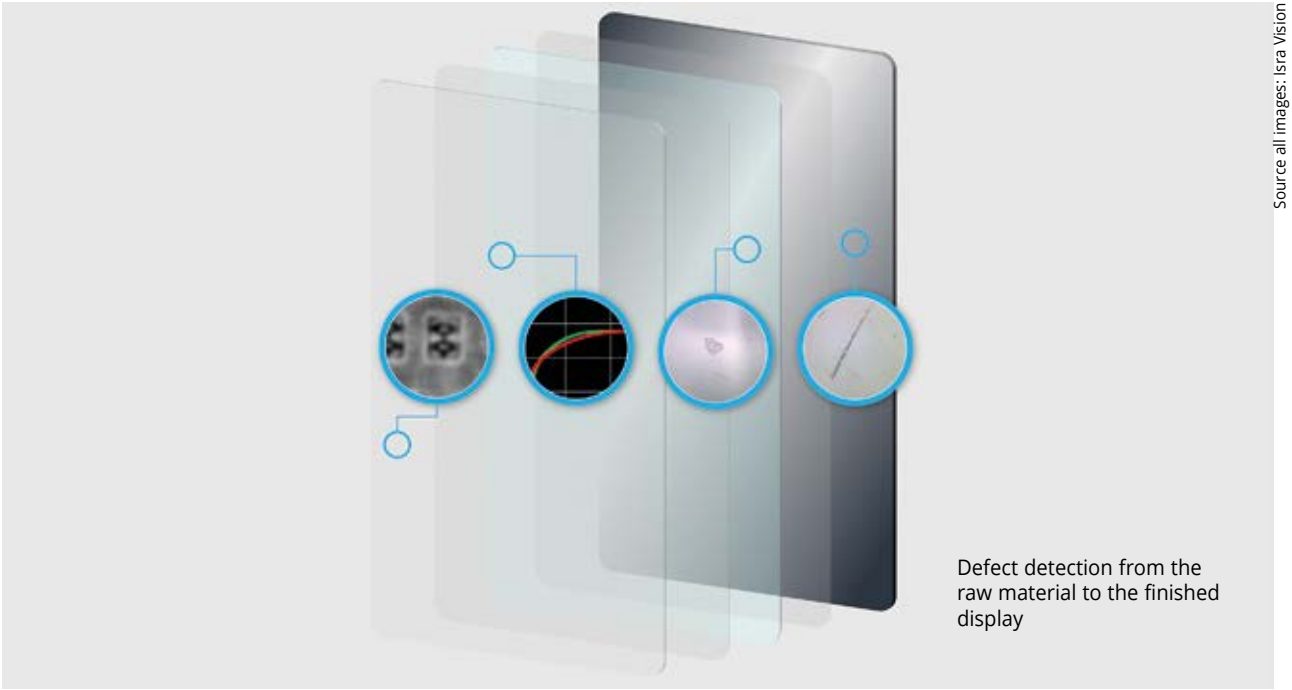
How inspection solutions ensure quality and profitability

Glass – display – smartphone: from the raw material to the final product



Source all images: Isra Vision

Defect detection from the raw material to the finished display

Technologies for ever thinner displays and vibrant display quality, outlandish shapes, and new applications open up additional market potential in consumer electronics and industrial markets. At the same time, however, they demand increasingly higher functionality and optical quality.

Have you looked at a display today? There is a good chance you will answer this question with 'yes' – after all, touch screens and displays are all around us, whether on our smartphones, coffee machines, ATMs, in our cars, or at our workplaces. To meet their tough standards, Isra Vision develops and produces mature inspection methods that track end-to-end process and quality control – from raw glass production, films, and foils, all the way to complete displays and finished products. These methods increase efficiency and profitability in the production of displays and, ultimately, boost customer satisfaction.

Touch displays enable the convenient and intuitive operation of devices and machines; plus, they are robust and easy to clean. As a result, they are also becoming increasingly widespread in production plants, medical technology, and other industrial applications. The automotive industry is currently setting trends with the introduction in new vehicle generations of pillar-to-pillar displays spanning the entire vehicle width. These present important cockpit functions and allow all the car's communication and infotainment systems to be operated. They also fit perfectly and often feature curved shapes and integrated sensors. It is expected that this trend will continue into other applications, but this will require new methods of glass processing and finishing, as well as the corresponding inspection processes during manufacturing. Such quality inspection is essential to meet the stringent requirements of robustness to mechanical loads, trouble-free functioning and operability, fit and optical quality.

Quality assurance begins with the raw material

Whether they employ TFT or OLED technology, modern displays consist of many layers made of different materials that are usually extremely thin. Optical films, thin-film, and thin-glass in the actual TFT or OLED display and the cover glass are joined together during the production process, achieving a perfect union of form and function. However, even the smallest defects in one of these layers can compromise the properties and function of the display. Isra Vision is an industry leader in optical inspection and defect detection for every single layer; its solutions identify and reject defective materials before installation, minimizing the number of imperfect end products produced and increasing the profitability of production. Isra Vision's SMASH is a system for inspecting the surfaces of

Isra Vision Flat Panel Master performing thin glass surface inspection for displays

optical films. It detects defects, including minute scratches, marks, and production residue on film materials and coatings on web materials. Line cameras guarantee a high inspection speed of up to 1,000 meters per second while also enabling the highest image resolution. At the same time, customized lighting supports the reliable detection and intelligent classification of defects that would be invisible to the naked eye. This allows conclusions to be drawn on the causes or defective process parameters, which can be continuously monitored and optimized.

Fully automatic inspection of display glass

Thin display glass is also subjected to a fully automatic inspection, just as optical films are. Isra Vision FPM-Inspect (Flat Panel Master) combines tried-and-tested optical quality control technology with precise materials handling technology for use in clean rooms. This allows the system to identify even the tiniest surface, glass, or edge defects. FPM-Inspect also monitors particle contamination on the substrate, enabling conclusions to be drawn on the air quality in the cleanroom. Here too, the inspection system works with mature software algorithms to improve the production process and to detect and eliminate the causes of defects. When it comes to the 100 % monitoring of evenness, rippling, and reflection optics, even in large glass surfaces, Isra Vision's P^2 (PowerPlate) delivers precise data in a matter of seconds. Alongside finding defects in and on the material, this also allows the immediate detection of 3D shape defects, preventing the materials in question from being processed further.

Quality control before and after joining

Perfect optical films, thin films, and display glass form the basis of high-quality displays. However, they only become a fixed unit with optical characteristics and functionality once they have been joined together during production. In this production step, quality control is just as important as inspecting the raw materials: dimples on the cover glass and other defects can occur when adhering the layers that cannot be recognized with the naked eye but compromise the optical properties and function of the product. SpecGage3D was specially developed to reliably detect local unevenness, supporting structures, or read-throughs before and after joining the display layers using deflectometry. To do so, a stripe pattern is projected onto the display and the reflection is captured by multiple cameras and subsequently evaluated (see image below left). Any detected defects are then classified immediately.

Curved glasses and displays – a special challenge

Deflectometry is perfectly suited for the inspection of curved glass and displays, for example for the cover glass of smartphones. Curved edges and

Deflectometric surface inspection of the end product

Company

ISRA VISION

The company has made a name for itself internationally over the last 35 years with innovative 3D machine vision systems and high-performance surface inspection. ISRA VISION offers a comprehensive portfolio of standard solutions for requirements throughout the entire process chain in automated production. Together with its subsidiaries, ISRA VISION is a global leader in the surface inspection of web materials and one of the market leaders for 3D machine vision.

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Isra Vision SMASH surface inspection system for plastic film material

concave shapes are becoming increasingly popular here and in the automotive industry since displays of the same size require a smaller installation width. And the shape allows information to be seen more easily on the edges. At the same time, they set even more stringent quality inspection requirements because the fit and shape as well as the surface and optical quality must be exactly right.

The SpecGage3D inspection system from Isra Vision enables the efficient and reliable shape inspection of curved and flat displays and plastic optics – such as light guides – by generating measurement data that is superimposed with the target data of a digital twin in a CAD comparison. It creates a difference-map of the inspected material that is precise to the nearest micrometer. The system uses point comparison, profile sections, or full-surface evaluation to reliably and efficiently check deviations from the target geometry and then to visualize them.

Bending molds are a possible source of defects in curved and flat displays. With NetGage3D, Isra Vision offers precision measurement technology for this too by reliably identifying defects in the graphite mold. This ensures flawless quality and reduces the likelihood of defects that could otherwise be reproduced in thousands of displays during production.

100 % quality control of the end product

The raw glass and foils are impeccable, no flaws occurred when adhering the parts together, and the finished display is fitted. Now it is time to perform a final check to ensure that the finished product has a perfect appearance and is free of errors. This is still often performed as a manual cosmetic inspection – with all its disadvantages such as subjective judgment, the dependency of the inspection result on the person carrying out the test, and the general limitation of the human ability to recognize minimal quality deviations. This final inspection has a great influence on the profitability of production: if minimal defects are screened too strictly it reduces profit, while an excessively relaxed quality inspection leads to complaints and dissatisfied customers.

A fast, fully automatic, and 100-% optical inspection solution solves this problem. It is easy to integrate, it detects typical cosmetic defects such as scratches, bubbles, indentations, and polishing marks, and delivers objective and reliable results. The SpecGage3D inspection system is also used during the final check and is ideally suited for the measurement and inspection of all transparent and reflective surfaces. Inspecting flat or curved displays, as well as 2D / 3D cover glass, glass back panels of smartphones, and other glossy housing parts is all possible with this inspection system. It immediately decides how to sort goods based on defined tolerance ranges and automated defect classification.

Crystal-clear quality thanks to end-to-end process monitoring

Increasingly larger and thinner glass, flexible materials, and complex shapes are raising the display manufacturing bar. To meet the stringent production standards and ensure the best possible quality while also achieving high productivity and process reliability, companies need end-to-end processes and quality control. It begins with the inspection of the raw materials and accompanies the entire production process right through to the end product. When defects are detected during this process, connected inspection solutions ideally allow them to be precisely linked to their cause in the upstream production steps. This also enables the effects of process parameter changes on all further processes to be tracked and monitored. Isra Vision offers a broad portfolio of optical inspection solutions for every step of display manufacturing. Thanks to the inspection data gathered, plant operators can continuously optimize their processes and achieve optimum product quality, production stability and, ultimately, profitability. As a result, they deliver flawless materials and products – and guarantee high customer satisfaction. The deployment of fully automatic inspection systems in production plants also ensures compliance with current and future quality standards as required, for example, in the automotive industry.

With 100 % optical inspection, you are also guaranteed to even meet future requirements for the shape, appearance, and function of displays in production. Isra Vision therefore collaborates closely with leading manufacturers and customers' development departments in all key industries and can call upon a close-knit network of experts and engineers in Asia, and indeed worldwide. Whenever new materials, technology, and applications necessitate the further development of inspection solutions, Isra Vision will already be working on their implementation in existing and new quality assurance systems.

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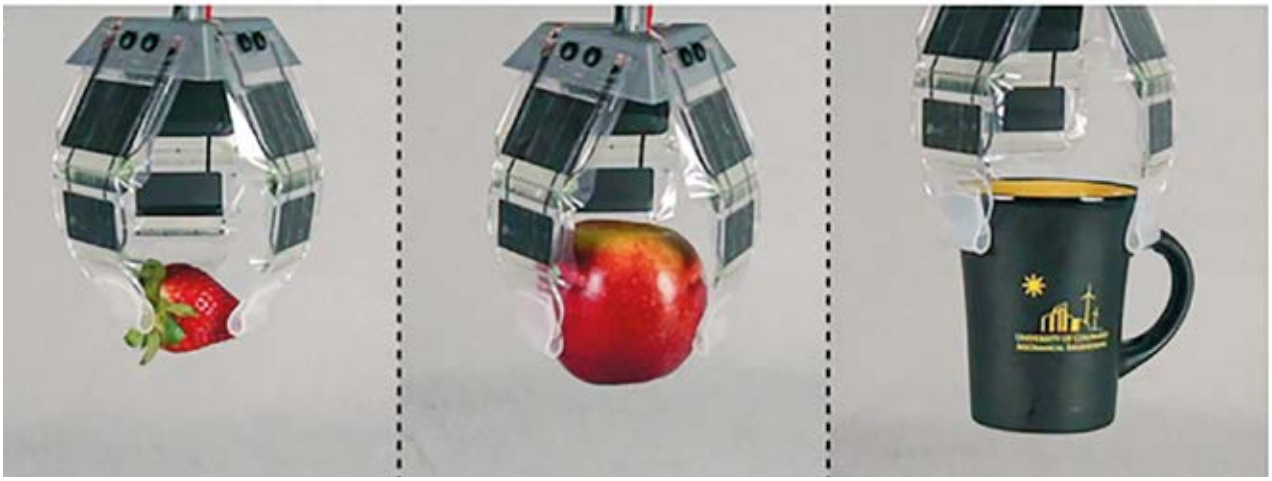
Bionic technology analyzed precisely

Ultrahigh-speed camera used in complex fundamental research



Source: *N. Kellaris* et al., Adv. Sci. 8, 2100916 (2021)

Complex fundamental research is necessary to realize future visions such as robotic humanoids with artificial joints and muscles. The Max Plank Institute for Intelligent Systems (MPI-IS) in Stuttgart, Germany, has dedicated itself to this research using a Phantom ultrahigh speed (UHS) camera for precise observation and versatile analysis of these complex processes.

In order to breathe life into bionic joints, small plastic bags filled with liquid (e.g. vegetable oil) are set in motion electrostatically. The strength and form of the electrical voltages applied determine the strength, type and form of movement. Several joints can be arranged in a geometric shape, one behind the other similar to a human finger, to imitate the complex mechanical processes of the human hand. This control is important as there is an enormous difference between grasping a raw egg and an object weighing several kilograms.

Precise analysis

The variable electrical voltage applied to the actuator/joint can be regulated in all its range of square, triangular, sinusoidal and linear voltages. Deformation of the bags as a function of time can thus be controlled very precisely. These bionics replicate the movements of insect legs (e.g. spiders) in terms of speed, power, and bidirectional movement. Of even greater importance is the replication of human extremities (fingers, hands, arms, legs). For over a year, the MPI-IS in Stuttgart has been researching the basics of understanding these complex, multilayered, bionic processes. This research work has also become known under the title of spider-inspired electrohydraulic soft-actuated (SES) joints.

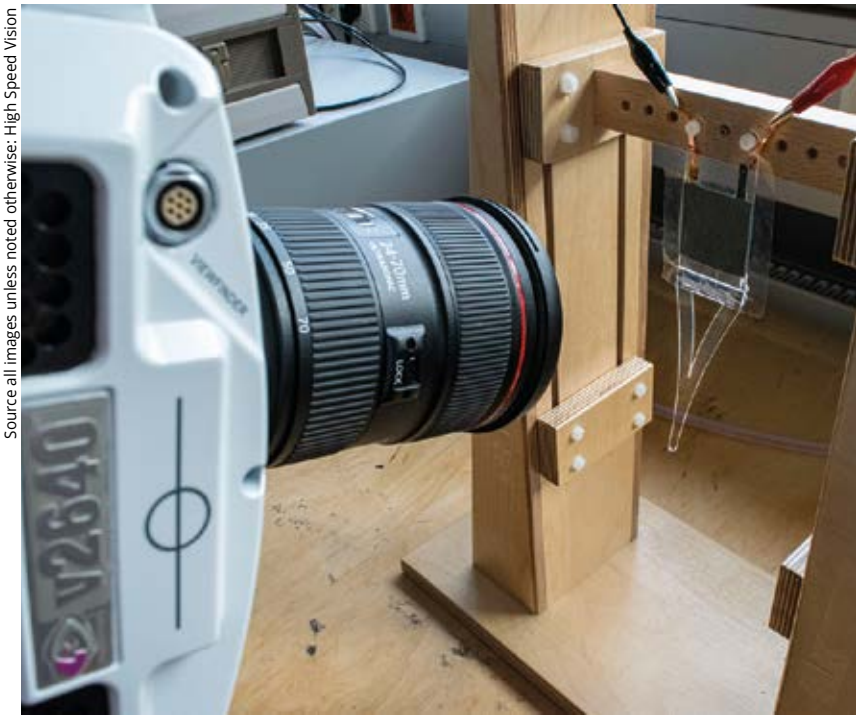
Equipped with the latest CMOS sensor technology, the Phantom v2640 camera offered by High Speed Vision provides the necessary ultrahigh-speed image sequences for precise motion analysis. This allows the quantitative and qualitative acceleration, speed, and movement behavior of an articulated arm to be followed very precisely – through slow-motion, high-resolution imaging.

Together with simultaneous tracking of the geometric deformation of these actuators, including the fluid flow occurring within them (flow behavior), researchers are able to analyze many other important aspects and functional factors. The high-speed (HS) video sequences enable detailed frame-by-frame analysis at strain rates of up to 7,000 %/sec. Working ranges of over 100,000 frames per second (fps) correspond to an increment of 0.01 milliseconds. These are recorded synchronously with other measurement data.

Logical processes in the range of milliseconds are recorded in their entirety, enabling precise information to be extracted. An example benchmark is a 1 cm long bag recorded at 0.1 ms with real Full HD resolution and 10,000 fps. This enables movement differences in the range of 0.001 mm to be captured.

▲ Several joints can be arranged like a finger – and combining multiples of them can form a hand. This can be used to lift a strawberry, an apple or a coffee cup.

Source all images unless noted otherwise: High Speed Vision



With these electrohydraulic actuators, the movements of insect legs, for example, are imitated and their exact analysis in speed, force and bidirectional movements is carried out

The Phantom v2640 CMOS camera provided by High Speed Vision delivers the ultrahigh-speed imaging capabilities required for accurate motion analysis.

Ultrahigh-speed video provides versatile precision

During the course of experiments, further questions continually arise. As a result, new requirements in the fundamental research on the SES joints must be examined in detail. The use of lasers only allows discontinuous measurements, whereas ultrahigh-speed video recordings enable the entire actuator geometry to be tracked, providing a wide range of precise information, both quantitative and qualitative. Small air bubbles in the liquid, for example, can be tracked simultaneously with the bag deformation and joint movement. This provides valuable information about the flow behavior of the liquid in the bag according to the voltage applied.

A major benefit here is the high image resolution of the Phantom v2640 with simultaneous and extremely fast frame rates. In accordance with its stringent requirements and in anticipation of further beneficial functions being added, the MPI-IS decided to purchase the Phantom v2640. High Speed Vision's extensive knowledge and expertise being available in an advisory capacity were also an important part of this decision.

The Phantom v2640 is the world's fastest 4-megapixel camera with a maximum resolution of 2048 × 1952 pixels at a frame rate of 6,600 fps and 12-bit image resolution In a reduced resolution, the camera offers 300,000 fps, and a minimum exposure time of 142 ns. In binned mode (2 × 2 pixels), photosensitivity is increased from mono 16,000 to 25,000 ISO.

This high photosensitivity enables recordings to be made in daylight, making handling easier and considerably simplifying the experiment setup. No complex additional lighting is necessary, thus avoiding possible external influences (heat input) that could impair the experiment. High photosensitivity also has the major benefit of being able

Experimental setup with Dr Philip Rothemund, postdoctoral researcher at the Max Planck Institute for Intelligent Systems (MPI-IS): "In basic research you constantly come across new questions, aspects and requirements. The ultrahigh speed camera used in our analysis offers a very high level of performance and wide range of functions."

Company

High Speed Vision

HS Vision GmbH is a leading system house for the entire application range of high-speed camera technologies. It has decades of extensive experience in the development of system solutions with high-speed cameras for root cause analysis in research, industrial automation and development. The extensive product portfolio of cameras, networking components, software and LED lighting is complemented by competent services.

www.hsvision.de

to close the lens aperture to a large extent to improve the depth of field.

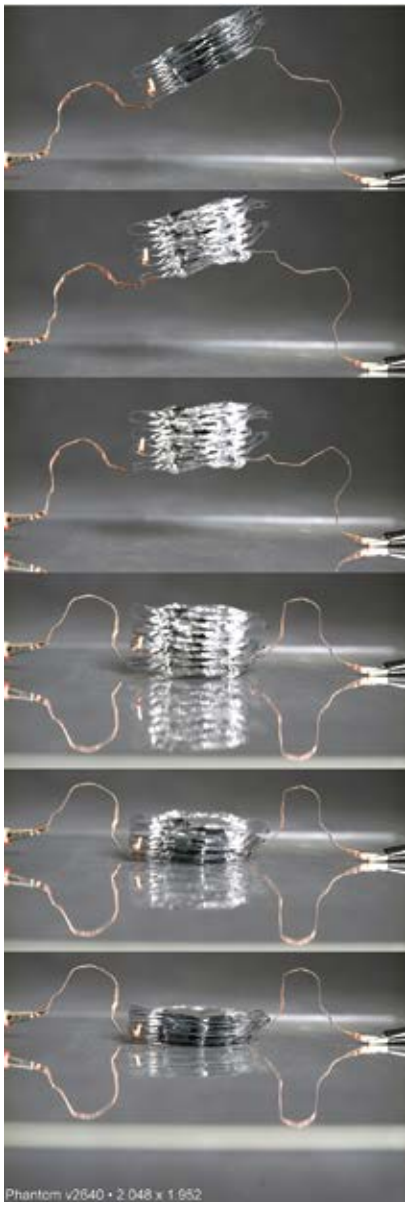
The Phantom v2640 also has more superlative performance data: an extremely fast internal sampling rate of 26 Gpx/sec and a ring memory upgradable to 288 GB; fast download speeds for data backup are available with the 10 GB Ethernet interface. Alternatively, there is the optional CineMag V storage with up to 8 TB volume, enabling 288 GB of data to be downloaded in less than five minutes. The menu-guided user interface enables easy camera operation.

Small details, big impact

The goal is to precisely measure all aspects of the ongoing dynamics with very high resolution. Combining and synchronizing different electronic measurement techniques with high speed imaging data allows those dynamics to be qualified and quantified.

The electro-hydraulic 'muscles' have a considerable advantage over the behavior and necessary design of electric motor solutions with the same tasks/results. This gives SES joints a high level of protection against overloading. Extremely sensitive and versatile control is possible by connecting several joints and several fingers in series. The first joint is powerful and the last joint is very gentle. This not only relates to the respective forces exerted, but also to the acceleration of the components of each joint. A future step is planned with an additional camera to open the 3D space using ultrahigh-speed video, with high time and image resolution for analytical precision.

The easy-to-control actuators also operate under water. Because the liquid in the bags is scarcely compressible, the surrounding water pressure does not negatively affect how strong or soft the grip is compared to operation on land. The joints can also be easily dipped in alcohol for disinfection.



The camera's 4-MP resolution guarantees the detailed recording of changes in deformation and movement speed of the actuators arranged one above the other.

Grand future

Bionic electrohydraulic actuators have enormous potential in terms of their design, application and cost- effectiveness in future soft robotics and other interacting areas. The following attributes are not exaggerated statements, but instead show just some of the emerging properties and possibilities of new applications. The soft-working joints are ingeniously simple, light, extremely agile, space-saving, easy and very cheap to produce. They are versatile in design from delicate to robust, with synergy of multi-part joints, minimal mechanical effort, low energy consumption, employ normal plastic foil, and are hygienically easy to care for. They are also waterproof, highly efficient with sensitive or strong power transmission, have easily scalable production, and are particularly easy to control digitally.

The outstanding strengths and international success of the many MPI disciplines and departments are the result of its entirely independent fundamental research. Because there are no sponsors to influence its work, MPI enjoys maximum freedom for successful research.

*

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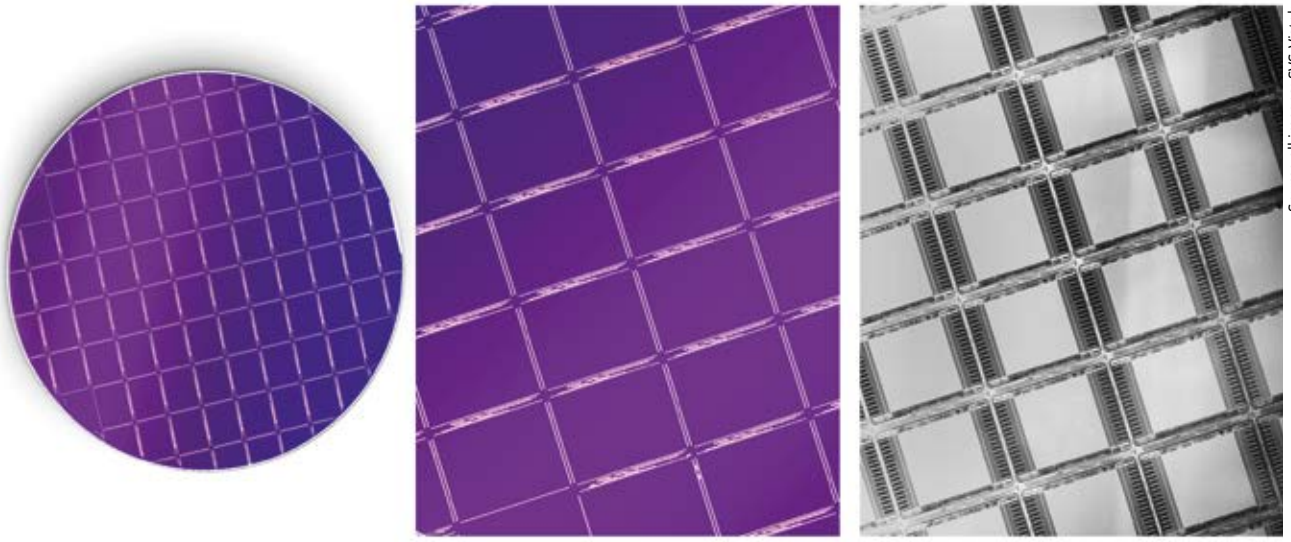
New at the short end of the spectrum

Image processing outside the visible range



Source all images: SVS-Vistek

For many industrial inspection tasks, wavelengths outside of visible light are more meaningful than the light spectrum perceivable by humans. New and powerful short-wave infrared (SWIR) and ultraviolet (UV) industrial cameras as well as polarization cameras are now available for such applications.

The human eye can detect light with wavelengths of about 400 to 750 nanometers. For many years, industrial image processing systems focused almost exclusively on this visible range. The economical use of special cameras outside the visible spectrum is now also possible in applications predestined for this thanks to the increasing performance of sensors in the SWIR and UV ranges.

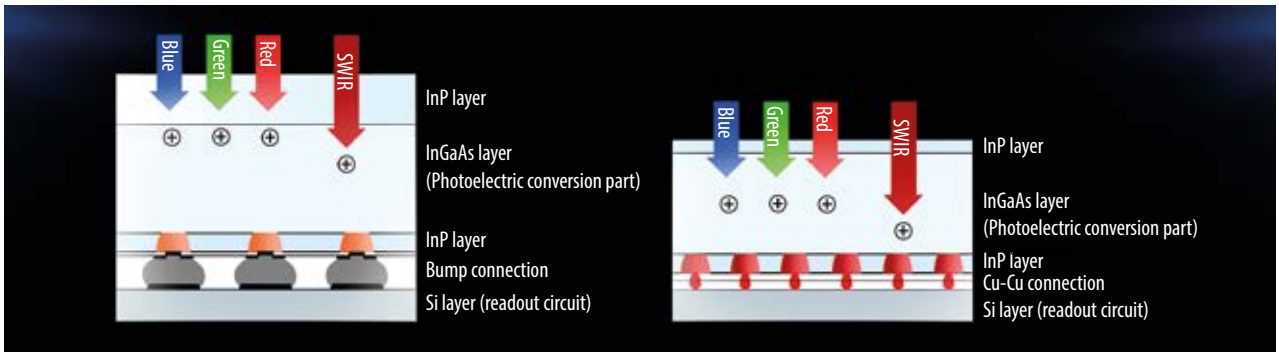
Inspection with SWIR cameras is already a proven technology in a wide range of industrial sectors. The new SWIR cameras from SVS-Vistek are able to cover the visible range of the human eye and the SWIR range with a single sensor. The combined use of the visible and SWIR ranges makes it easier, for example, to detect contamination as well as rot or pressure marks on fruit or vegetables on the selection belt,

▲ Defects on wafers that remain undetected during inspection with visible light (left and center image) can be clearly detected with SWIR cameras (right image).

SVS-Vistek's special UV camera is as easy to handle as a standard machine vision camera.

to inspect silicon in the solar and electronics industries, or to identify invisible impurities, water or water vapor with other technologies. Requiring only a single sensor for the complete wavelength range from 400 to 1700 nm results in significantly lower costs and less complex inspection systems.

SVS-Vistek currently has three powerful models in its range: the exo990, fxo990 and exo991 SWIR cameras. With a resolution of 0.3 MP or 1.3 MP, frame rates of 90 to 259 fps, a very compact sensor format with a diagonal of only 8.2 mm or 4.1 mm, excellent temperature management and modern interfaces such as GigE Vision and CoaXPress-12, they are suitable for a wide range of applications. The cameras deliver excellent image homogeneity across the entire spectrum from 400 to 1700 nm. The technical basis is Sony's



With their Cu-Cu bonding, the Sony SenSWIR sensors used in SVS-Vistek's SWIR cameras result in smaller pixel structures and provide higher resolution. Left: Bump connection; right: Cu-Cu connection.

SenSWIR sensors, which are currently unrivaled on the market in this quality. A significant improvement compared to previous SWIR sensors is the so-called Cu-Cu bonding that enables smaller pixel structures and improved resolution. State-of-the-art InGaAs technology, high resolution and sensitivity over a wide spectral range are the basis for the industrial SWIR cameras from SVS-Vistek.

The use of ultraviolet wavelengths, which lie in the spectrum from approximately 200 to 400 nm, has been less popular in industrial inspection than the use of SWIR-based cameras due to the hitherto low resolution available from UV cameras. SVS-Vistek is fundamentally changing this situation with its new fxo487MCX and fxo487MXGE UV cameras. The 8.1 MP Sony sensor integrated into these cameras enables the detection of otherwise invisible product defects through ultrasharp, high-resolution UV images. The most important areas of application for these cameras equipped with a CoaXPress-12 or a 10GigE interface are complex inspection tasks, for example in the battery, semiconductor, glass, recycling, gemstone and automotive industries.

Polarized cameras

Another interesting field for industrial inspection is polarization cameras. Here too, a sensor development by Sony provides the basis for this innovative technology. The IMX264MZR, IMX250MZR and IMX253MZR polarized sensors work with a matrix of polarizing filters of different orientation (0°, 90°, 45° and 135°), which is applied directly onto the sensor in each 2 × 2 pixel array. This setup has the advantage that, with a single acquisition and without changing the illumination, the degree of polarization of the light, its polarization direction and the intensity of the polarized light can be measured and evaluated simultaneously. The simultaneous detection of different polarization directions and degrees enables reliable image evaluation on an optical basis. Changes to the mechanical or optical settings on the lens or the illumination are not necessary, which simplifies many tasks in image processing.

Based on these innovative sensors, SVS-Vistek currently offers six polarized models of the EXO series with 5 or 12 megapixel resolution and frame rates from 10 to 75 fps. Users can choose between Gigabit Ethernet and USB3 interfaces. With these polarized cameras, SVS-Vistek opens up interesting new possibilities compared to conventional industrial cameras. Polarization measurement allows, for example, non-metallic transparent or reflective materials such as water, plastic or glass to be inspected, as well as the inspection of difficult surfaces or the reading of black lettering on a black background, which was previously an almost impossible task in tire production, among other things. In the pharmaceutical industry, polarization cameras are particularly suitable for blister inspection in order to reliably detect and sort out defective tablet packaging or assemblies.

With a wide range of SWIR, UV and polarized cameras as well as optimally matched illumination and optical components, SVS-Vistek is once again demonstrating its technical expertise in industrial image processing, even outside the visible light spectrum, and will be happy to advise users on selecting the optimal combination for the task at hand.

Polarization cameras enable reliable inspection of transparent or reflective materials.

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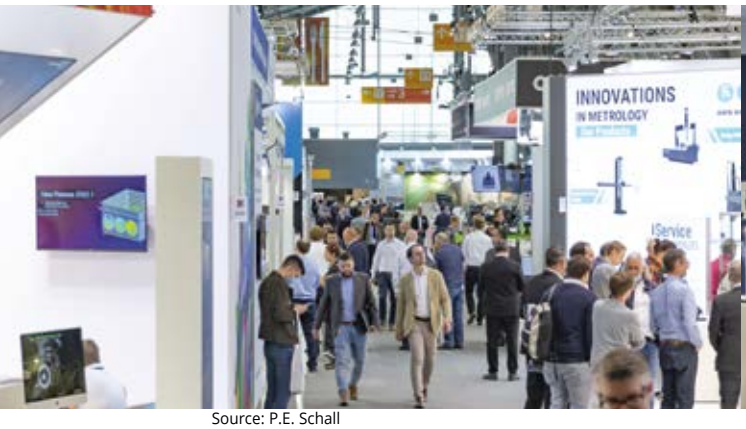
Meet us: VISION, TKH Vision Booth 10 F30



Source: P.E. Schall

Source: Palexpo / Tema

September 04 – 08, 2022

12th CIRP Conference on Photonic Technologies [LANE 2022]
Fürth, Germany
www.lane-conference.org

September 06 – 08, 2022

Optics and Photonics Days (OPD2022)
Tampere, Finland
www.photonics.fi/opd2022

September 07 – 08, 2022

EPIC Meeting on CMOS-Compatible Integrated Photonics
at Imec, Leuven, Belgium
https://epic-assoc.com/events

September 07 – 09, 2022

24th China International Optoelectronic Exposition (CIOE)
Shenzhen, China
www.cioe.cn

September 12 – 16, 2022

EOS Annual Meeting (EOSAM) 2022
Porto, Portugal
www.europeanoptics.org/events/eos/eosam2022.html

September 18 – 22, 2022

European Conference on Optical Communication (ECOC)
Basel, Switzerland
www.ecoc2022.org

September 20 – 23, 2022

glasstec
Dusseldorf, Germany
www.glasstec.de

October 04 – 06, 2022

VISION 2022
Stuttgart, Germany
www.messe-stuttgart.de/vision

October 17 – 20, 2022

41st annual International Congress on Applications of Lasers & Electro-Optics (ICALEO 2022)
Orlando, Florida, USA
https://icaleo.org

October 18 – 20, 2022 NEW DATE

Optatec
Frankfurt, Germany
www.optatec-messe.de

October 19 – 26, 2022

K2022
Dusseldorf, Germany
www.k-online.com

October 25 – 28, 2022

EuroBLECH
Hanover, Germany
www.euroblech.com

November 08 – 11, 2022

electronica
Munich, Germany
https://electronica.de

November 14 – 17, 2022

MEDICA / COMPAMED 2022
Dusseldorf, Germany
www.medica.de / www.compamed.de

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"Perfect moment for comeback event"

Review: Hannover Messe, 30 May – 2 June 2022, Hanover, Germany

The first Hanover Fair for two years was a success for exhibitors and organizers. The trade fair has shown that industrial transformation is making great strides and that industry can already provide answers to the challenges of climate protection and security of supply.

At the same time, it became clear that trade fairs, as a meeting place for people, will remain key business and innovation drivers in the future. "The comeback of the Hannover Messe came at exactly the right time," says Dr Jochen Köckler, CEO of Deutsche Messe. "In view of the interrupted supply chains, rising energy prices, inflation and climate change, it was all the more important to meet again in person in the exhibition halls after two years of the pandemic, to experience technology trends and to look ahead. After four days of the fair, industry, politics and science are broadcasting a clear signal from Hanover: pandemic and war must not and will not slow down industrial transformation – on the contrary, we need even more speed in digitization and sustainability."

Around 75,000 visitors exchanged views with the 2,500 exhibitors on how they can align their value chains for the future. The visitors learned how they use automation and digitization to reduce the energy consumption of their factories and production facilities, how they operate their production with electricity from hydrogen or how they expand the resilience of their supply chains. From major solutions such as the digitization of development and production processes in automotive engineering to algae as a substitute for plastic and the targeted use of software to record and reduce the carbon footprint, the Hanover Fair offered a broad picture of the technological possibilities for the industry of today and tomorrow.

"With its thematic focus on energy, security of supply and industrial transformation, Hannover Messe 2022 has impressively demonstrated that we need such a leading flagship fair – more than ever after two years of pandemic," declared VDMA executive director Thilo Brodtmann. "In an environment that was more challenging than ever, the exhibits showed there is no substitute for personal contact. This applies to the relationship between companies and their clients or the next generation, but also to high-level discussions with politicians, for which Hannover Messe represents the ideal venue."

Source: Deutsche Messe

German Economics Minister Dr Robert Habeck (2nd f. r.) touring the tradeshow on Tuesday

In addition to 75,000 visitors on the exhibition grounds, another 15,000 registered visitors took part in the event digitally. They followed the conference program, obtained information from the digital product presentations and held discussions via chat or video call.

The next Hannover Messe will be held from April 17th to 21st, 2023.

www.hannovermesse.de

Switzerland's largest trade fair celebrates its anniversary

Review: 20th EPHJ, 14 – 17 June 2022, Geneva, Switzerland

EPHJ, the international high-precision trade fair, has completed its 20th anniversary edition with a clear increase in numbers compared to the 2021 edition and in the quality of visitors welcomed by the 700 exhibitors.

As the doors of the world's only trade fair dedicated to high precision watchmaking, jewellery, microtechnology and medicine closed, the organisers were smiling. "We knew that visitor numbers would be higher than in September 2021, when the health crisis ended," explains Alexandre Catton, EPHJ director. "However, this has exceeded our expectations. This development reflects the market trend, particularly in the watch industry, in which the order books tend to be quite full."

More than 700 companies from all over Switzerland and 14 other countries came together to celebrate EPHJ's 20th anniversary. 18,000 Swiss and international trade visitors passed through the gates of Palexpo this year, which is an increase of more than 33 % over 2021. "We are gradually witnessing the return of foreign visitors, who will certainly be even more numerous in 2023." In the opinion of the exhibitors, the quality of the visitors made the difference.

Several highlights marked this 20th edition, including the last day being dedicated to job dating to attempt to fill the 300 vacant positions in these companies. At the start of the EPHJ, the results of a questionnaire among young Swiss people were published that looked at their opinion of watches, whereby the allegiance of these young people to fine, mechanical watches in the light of the remarkable progress of smart watches could be assessed.

EPHJ 2022 (Source: Tema)

It should also be mentioned that the 2022 Exhibitors' Grand Prix was awarded to Polycrystal for its transparent ceramics. Altimet, winner of the Watch Medtech Challenge, is an innovative company that can predict the wear and tear of implants.

Following the closure of this 20th edition, the EPHJ show returns from 6 – 9 June 2023 at the Palexpo in Geneva.

https://ephj.ch

LASYS holds its own in a strong market environment

Review: LASYS international trade fair for laser material processing, 21 – 23 June 2022, Stuttgart, Germany

Source: Messe Stuttgart

Lasys 2022 in the Mahle Hall again

The seventh edition of Lasys ended on June 23 amidst a positive mood. In Mahle Hall 4 at the Messe Stuttgart trade fair, trade visitors from all over Europe gathered information from a total of 93 exhibitors from 16 countries.

The proportion of international exhibitors was 34 %. "Lasys has fared well in a strong market environment with many major events in May and June of this year. With its clear focus on laser material processing, Lasys provided an attractive market platform to interested trade visitors," says Roland Bleinroth, president of Messe Stuttgart.

This year's Lasys trade visitors once again came with a high degree of decision-making authority. Around one fifth were from business/corporate and operational management. A similar number are actively involved in development, with around 16 % from manufacturing, production and quality assurance. A very large proportion – 81 % – are decisive, co-decisive or consultative in their institution's purchasing decisions. Three quarters of them have a specific intention to invest or purchase, and 25 % of those future buyers plan to invest more than 200,000 euros.

Just under three quarters of the trade audience came from industry and already use lasers or laser systems in their own company – i.e. they use Lasys as a platform to keep up-to-date with developments in their systems and other application potential. The most prominent industries represented by visitors were mechanical engineering, automotive engineering, plant and apparatus engineering, the metal and manufacturing industry, and the optical industry. The trade audience was interested in the many applications and laser systems for surface finishing, separation, labelling and marking, and joining. Laser systems for additive manufacturing and beam sources were also in focus. Overall, the visitors agreed: with a rating of 2.3, Lasys was rated good on average. 85 % of trade visitors are already planning to visit again in 2024.

The trade audience also benefited from Lasys' conference and activity programme: complementing exhibitors' products and services, it gave visitors the opportunity for in-depth sharing of expertise across all three days. As is tradition, this included the Stuttgart Laser Days (see below), the EPIC Meeting on Beam Shaping, the expert presentations from the Wissenschaftliche Gesellschaft Lasertechnik eV (WLT) and the Solution Center with six participating laser institutions, which all offered great opportunities to transfer knowledge between the worlds of research and industry. The programme was rounded off by the 'Lasers in Action' forum and several subject-specific workshops and seminars.

The next Lasys will take place on 4 – 6 June, 2024 at Messe Stuttgart.

www.messe-stuttgart.de de/lasys/

"The universal laser machine"

Review Stuttgart Laser Technology Forum 2022, Stuttgart, Germany, 21 – 22 June 2022

Source: IFSW, U Stuttgart

SLT 2022 opening speech by Prof Thomas Graf

After a Corona-related break in 2020, highlights and innovations in industrial laser-based manufacturing brought together some 180 experts and users at the 11th Stuttgart Laser Technology Forum (SLT) in June 2022.

The SLT is an international, scientific conference that takes place every two years and always presents current research results and future trends. The conference with a total of 44 lectures covered topics from micro to macro-processing together with the required laser sources and beam delivery systems. It is organized by the Institut für Strahlwerkzeuge (IFSW) of the University of Stuttgart and always takes place in conjunction with the Lasys.

The relaxed time schedule together with the pleasant surroundings of the Lasys fair once again provided the conference topics with an ideal environment for active and successful networking. An evening event following the first day of the SLT 2022 provided further opportunities for exchange, including a guided tour through the laboratories of the IFSW.

Many representatives of research, development and industry took part in the conference. The presentations were held in English and German, with simultaneous translation. On 21 June Dr Andreas Michalowski, Bosch Research, talked about "Towards automated self-learning process optimization". Dr Christian Schmitz, Trumpf, gave a presentation entitled "Industrial laser processing: What's next?"

Highlights on 22 June were a talk by Prof. Ludger Overmeyer, Leibniz University Hannover, about "Additive manufacturing under space conditions using the Einstein elevator", Winfried Kaiser about "The (r)evolution of lithography optics: EUV enables the continuation of Moore's Law" and Prof Thomas Graf, Institut für Strahlwerkzeuge at the University of Stuttgart, about "On the way to the universal laser machine".

The next SLT will take place on 4 – 5 June 2024.

www.slt.uni-stuttgart.de

The enabling technologies met live

Review: W3+ Fair, 6 – 7 July 2022, Wetzlar, Germany

There were many satisfied faces on the evening of July 7 when the doors of the W3+ Fair Wetzlar 2022 closed after two days. 126 exhibitors, partners and sponsors and more than 1,500 visitors had made their way to the Buderus Arena Wetzlar to talk shop about new innovations and solutions and to network across industries. The exhibitors of the enabling technologies around optics, photonics, electronics and mechanics came from eleven countries: in addition to Germany and Switzerland, France, Great Britain, USA, the Netherlands, Denmark, Ireland, Czech Republic, Lichtenstein and China were represented at the event.

Besides the exhibition, there was plenty of inspiration from the extensive supporting program. This year, the accompanying conference en-tech.talks took place on two stages. In addition to presentations on new technologies, business opportunities, applications and Industry 4.0, there were interesting lecture blocks on the top topics of defense and security, supported by OptecNet Deutschland, and 'quantum'.

Also new were the High-Power Laser Workshop from Wetzlar Network, the forest@photonics workshop from OptecBB, the 'IHK Hessen innovativ' area, the Start-up Pitch from Regionalmanagement Mittelhessen, the C-Level Coffee from Wetzlar Network, the VDI special area with the networking breakfast, the visit of two specialist working groups from IHK Gießen-Friedberg, and the special area from EOS / Additive Minds Academy. In total, more than sixty speakers offered their expertise on the conference stage or in the workshops.

Jörg Brück, project director of the W3+ Fair, draws a positive conclusion after the fair: "Networking needs personal encounters – the fair has shown that again. The new start in Wetzlar after the Corona break was very well received by all exhibitors and visitors. For the upcoming W3+ Fair, we are counting on even more inspiration from new Innovation Areas and expanded networking opportunities."

Source: Fleet Events

W3+ Fair, 6 – 7 July 2022, Wetzlar, Germany

Upcoming events: the next W3+ Fair Rhine Valley 2022 will take place on 30 November and 1 December in Dornbirn, Austria. The W3+ Fair Wetzlar 2023 follows on 22 – 23 March 2023.

https://w3-fair.com

Preview: EPIC Meeting at Imec

On 7 – 8 September 2022, the EPIC Meeting on CMOS-Compatible Integrated Photonics at Imec, Leuven, Belgium, will bring together CMOS / silicon / electronics / MEMS foundries and manufacturers and providers of new materials with photonic functionality to address the need to initiate new collaborations.

The incorporation of new materials with photonic functionality to CMOS processing has been traditionally challenging. However, there has recently been major interest in bringing the developments in photonics to mass production and, for that, working closer to semiconductor companies is a necessary step.

Some of the recent trends are the mass production of coherent transceivers for FMCW lidar, efficient detectors based on quantum dots for next generation imagers, Intel hybrid IIIV/Si laser integration, the graphene flagship, and the GF 300 mm platform.

https://epic-assoc.com/events

Preview: 30th VISION

4 – 6 October 2022, Stuttgart, Germany

The Messe Stuttgart team is drawing on the positive sentiment that followed last year's successful trade fair. "The machine vision industry is seeing dynamic development while continuing to increase in importance. As a result, the outlook for Vision 2022 is promising and expectations are high. We are delighted to welcome industry players to Stuttgart for the 30th iteration of the world's leading trade fair for machine vision. Vision 2022 is the first Messe Stuttgart event to return to particular international significance following the restrictions put in place as a result of the Covid-19 pandemic," says Roland Bleinroth, president of Messe Stuttgart.

Anne Wendel of the machine vision sector group of the VDMA Robotics + Automation Association, underlines the development of the machine vision industry: "The industrial machine vision industry is experiencing full order books. According to a VDMA market survey, sales in the European machine vision industry increased by 17 % in 2021. The prognoses for 2022 remain largely favourable despite lower expectations due to supply chain disruptions. The VDMA predicts that the German machine vision industry will grow by 5 % and see sales of € 3.2 B. The robotics and automation industry on the whole is expected to see growth of 6 % at € 14.4 B. This allows us to be optimistic for the upcoming Vision 2022 trade fair."

Visitors from all over the world will spend three days meeting with start-ups and key players. So far, more than 300 companies – already more than last year – have signed up for Vision 2022.

The great international significance of the Vision trade fair has already been demonstrated by the large proportion of international exhibitors: the percentage of exhibitors from abroad for the 2022 edition follows an almost 50/50 ratio of national to international exhibitors in 2021. This year, exhibitors from the US are especially heavily represented, followed by Japan, China, the Netherlands and Switzerland.

www.messe-stuttgart.de/vision

Preview: Optatec 2022

18 – 20 October 2022, Frankfurt/Main, Germany

Optatec will once again be affected by the Europe-wide postponement of trade fairs in 2022. Now that Laser in Munich has been postponed to the even-numbered years – close to the scheduled dates for Optatec in May – the organizers had decided to postpone Optatec until September.

Meanwhile Messe Frankfurt had to postpone the dates for Light+Building, from March until October, which means that the setup times for this event, which occupies the entire exhibition center, would have overlapped with Optatec in Hall 3.

Consequently, Optatec has been postponed again by three weeks, associated with a change of location, so that Optatec 2022 will not be held in Hall 3 as usual, but rather in Hall 8. This decision was made in close consultation with the trade fair advisory board, a large majority of whom support the postponement.

Optatec focuses on the industry's innovation potential like no other event of its kind. In cooperation with technological and institutional partners including the Spectaris association for the high-tech industries, Optence and OptecNet, it offers an international showcase for advanced technologies. Exhibitors from all over the world will display future technologies from industrial optics and take the opportunity to present their innovations and product premieres. With its specific products for development and production, as well as industrial use of optical components, optomechanics, optoelectronics, fiber-optics, laser components and manufacturing systems, Optatec has become well-established within the industry sector.

www.optatec-messe.de

Preview: Day of Photonics

21 October 2022, activities in more than thirty countries worldwide

On 21 October 1983, the General Conference of Weights and Measures adopted the value of 299,792.458 km/s for the speed of light. Since then, on the anniversary on this event, the international photonics community has celebrated the Day of Photonics with the aim of promoting photonics towards the general public, to raise awareness about what photonics is and why it is important, to demonstrate the role of their organization in the photonics ecosystem and value chain, and perhaps most importantly, to encourage young minds to consider a career in photonics.

Activities, which are self-organized on a voluntary basis, will take place in more than thirty countries around the world to showcase the impact of photonics on our everyday lives.

Demonstrations, presentations and discussions will focus on developments across the whole spectrum of photonics technologies from LED lighting, lasers, sensors, imaging and displays to photovoltaic solar energy, photonic integrated circuits, and quantum, and their applications in health, security, agriculture, food, communication and transportation.

Every company, university, association and institution involved in photonics is invited to participate and to organize an activity for the Day of Photonics 2022.

To find out more about how you can participate in the Day of Photonics 2022, and to access various free materials such as logos, guidelines, templates, invitation letters to engage your stakeholders and to promote your support, please go to:

https://day-of-photonics.org

Preview: EuroBLECH 2022

25 – 28 October 2022, Hanover, Germany

Taking place again at the Hanover exhibition grounds in Germany after four years, the sheet metalworking community is looking forward to the industry's prime trade event. Euroblech is the largest exhibition for the sheet metalworking industry worldwide and is the marketplace to discover and source the latest innovative manufacturing solutions.

Numerous live demonstrations at the exhibition stands offer trade visitors the opportunity to experience machines and systems from all branches of sheet metal working in action. The exhibition profile covers fifteen technology sectors and therefore covers the entire sheet metalworking technology chain: sheet metal, semifinished and finished products, handling, separation, forming, flexible sheet metalworking, tube/section processing, joining, welding, additive manufacturing, surface treatment, processing of hybrid structures, tools, quality control, CAD/CAM/CIM systems, factory and warehouse equipment as well as R&D.

The exhibitor list, available on the EuroBLECH website, is regularly updated and provides plenty of information on exhibiting companies, such as exhibitor profiles, company videos and contact details. The EuroBLECH e-news, which is sent out frequently ahead of the show, provides the latest news about the event, the exhibitors and the industry sector.

Euroblech 2022 will be held in halls 11 – 17, 26, and 27 at the Hanover exhibition grounds. The opening times are from Tuesday, 25 October to Friday, 28 October, from 9 am to 6 pm. International flight connections, as well as the excellent local infrastructure make the venue in Hanover easily accessible by plane, car and public transport.

www.euroblech.com

Components and accessories

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F +49 9228 9977 149
E info@kkt-chillers.com
W www.kkt-chillers.com

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Fiber lasers up to 100 W

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info@zuendoptics.com
www.zuendoptics.com

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Free-form optics

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www.trionplas.de

Galvanometer Scanning Systems

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Mirrors

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Optical Components

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Windows, optical

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Material processing systems

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www.lpkf-laserwelding.de

Marking systems

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info@polytec.de

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Email: office@essentoptics.com
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