Volume 19 February/March 2022

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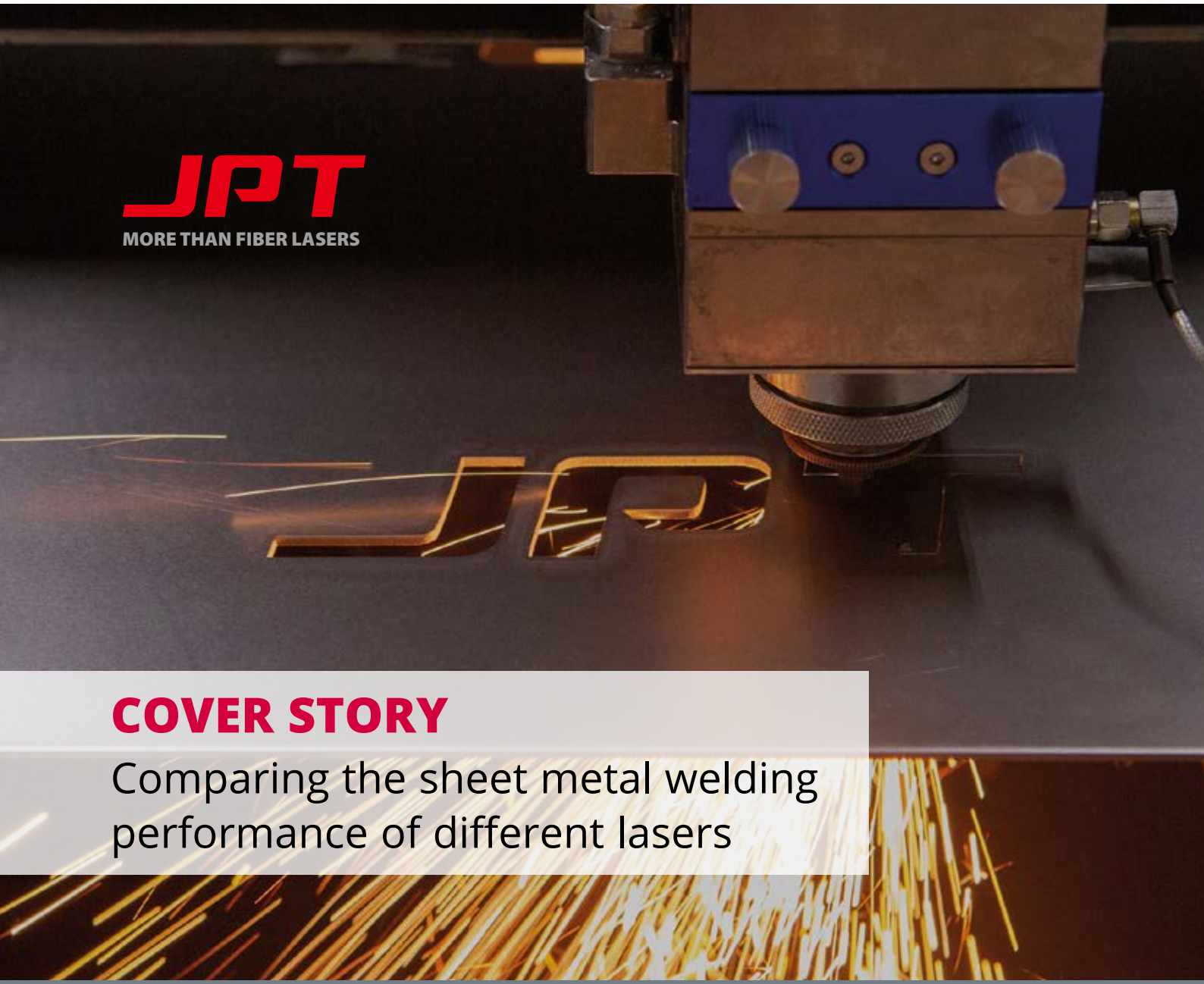
PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY



COVER STORY

Comparing the sheet metal welding performance of different lasers

Silicon Photonics
Programmable chips for 5G applications

Beam Shaping
Microfluidic chip sealing using femtosecond lasers

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GIT SICHERHEIT GIT SECURITY EMEA

Innovation is the engine of progress

In 2022 the term photonics is in common use and nearly everybody knows or uses at least one application of optical technologies for transmitting, processing or storing information. It is astonishing that photonics came into wider use only at the beginning of the 1980s, bringing to mind what progress we have achieved in only forty years.

Micro-optical structures can be found in sensors for safety applications, controlling industrial processes or switching devices. LEDs illuminate entire buildings in a bright and energy-efficient way; lasers are used as standard tools in medicine and material processing. Smartphones are our permanent companions, being continuously improved by innovations in display technology, semiconductor lithography, camera optics, and photonics sensor technology. New developments in microscopy help us better understand biological processes; with optical tweezers we are able to manipulate and investigate elusive micro and nanoparticles at will. Optical and quantum computing is seen as the next big step in optical technology with potential applications not even conceivable at the moment. And the list could be continued endlessly.

Optics and photonics are fascinating working fields with an enormous potential for innovation and nearly daily new discoveries – and yet there is still so much more to discover, investigate and learn (and not least marvel at).

The DGaO, as the German Branch of the European Optical Society, is proud to operate in such an innovative environment – and that for much longer than photonics itself exists as a research field. Celebrating our 100th anniversary next year, we are as innovative as our working field and stay young with our members. Connecting students and young scientists with experienced researchers, innovative start-ups and well-established high-tech companies creates the basis for fruitful and creative cooperations and guarantees future innovations.

But in most cases it is a hard and long way from the first idea at the breakfast table to a new technology or product for everybody's use. Research and development needs time, patience – and money. The new three-party coalition in Germany has committed itself to a strong science landscape and declared an increase in government funding of science and universities. I hope the success of the new science politics is as colorful as that broadband red-green-yellow alliance promises and wish all readers a perfect start to 2022. With a good portion of patience and self-confidence we will master the challenges of this year and the years to come.

Stay healthy, optimistic and curious.

Ricarda Kafka

Source: private

Ricarda Kafka
President, DGaO
Managing Director, TRIOPTICS Berlin GmbH

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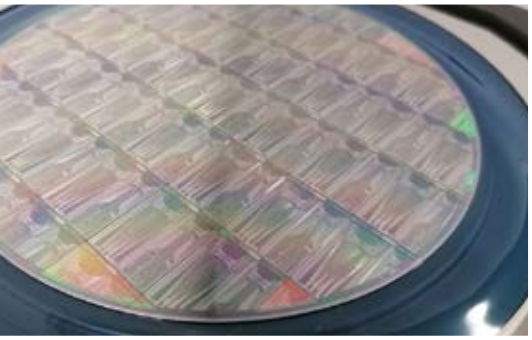
OPTICS • PHOTONICS • LASER TECHNOLOGY



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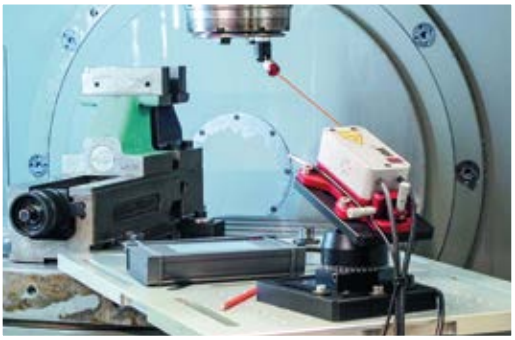

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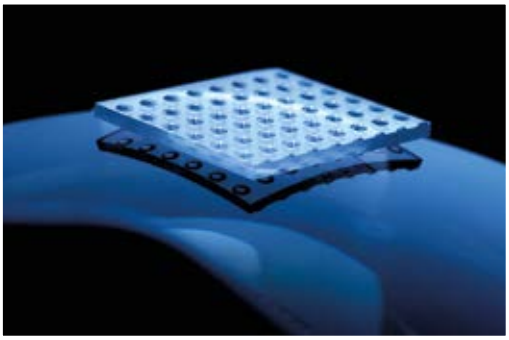

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Cover:

JPT offers laser sources for a wide range of laser material processing like cutting, welding, marking and drilling.

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Lumentum to acquire NeoPhotonics

The transaction of approximately $ 918 M has been approved by the board of directors of both companies. The addition of Neophotonics expands Lumentum's opportunity in some of the fastest growing areas of the more than ten-billion dollar market for optical components used in cloud and telecom network infrastructure. The integrated company will be better positioned to serve the needs of a global customer base who are increasingly utilizing photonics to accelerate the shift to digital and virtual approaches to work and life, the proliferation of IoT, 5G, and next-generation mobile networks, and the transition to advanced cloud computing architectures.

Alan Lowe, Lumentum president and CEO, said: "Adding Neophotonics' differentiated products and technology and innovative R&D team is consistent with our strategy, and together we will better meet the growing need for next generation optical networking solutions."

"[This] is an exciting milestone for us," said Tim Jenks, Neophotonics' president, CEO, and chairman. "The increasing global demand for our ultrapure light tunable lasers and photonics technologies for speed over distance applications is more apparent than ever, and Lumentum is the ideal partner to serve our customers on a larger scale. I look forward to an exciting new chapter as one company."

www.lumentum.com
www.neophotonics.com

Hübner Photonics acquires Valo Innovations

The German-Swedish manufacturer of high performance lasers for advanced imaging, detection and analysis, has expanded its technology portfolio to include short-pulse femtosecond fiber lasers, with the recent acquisition of Valo Innovations. Their proprietary fiber laser technology delivers market-unique, short pulse performance. With pulse lengths of <50 fs and peak powers of >2 MW from compact and stable turnkey systems for applications in bioimaging, spectroscopy and micromachining.

Source: Hübner Photonics

Dr Håkan Karlsson, Hübner Photonics (right), Dr Oliver Prochnow, Valo Innovations

Valo Innovations remains in Hannover and its lasers will become a new product-line, adding to Hübner Photonics' broad portfolio of high performance laser products.

"We are extremely excited to add the unique fs laser technology of Valo Innovations to our group. Their innovative mind-set, engineering capabilities and customer orientation make a perfect fit with us and we are very much looking forward to being able to offer our customers these highly complementary products in the short-pulse regimes," says the head of Hübner Photonics, Dr Håkan Karlsson.

Dr Oliver Prochnow, co-founder and CEO of Valo Innovations is equally excited, stating "We both share the same views and we are looking forward to the opportunity of accelerating our market access with Hübner's support."

www.hubner-photonics.com
www.valo-innovations.com

GML and Framos: 'life-ready AI' for 3D industrial vision

Framos and GrAI Matter Labs (GML), a pioneer of brain-inspired, ultralow latency computing solutions, have united at Vision 2021 to create 'life-ready artificial intelligence' for industrial vision platforms.

This project is based on Framos' D435e industrial depth camera and GML's GrAI VIP (vision inference processor) and was formed to advance vision application development in robotics, automation, IoT-connected manufacturing, and more.

Source: GML

Live-ready AI conveyor belt sorting with a Framos D435e industrial depth camera

The platform offers full bodied IP66 rated cameras, or board level modules that are enabled with ultralow latency AI processing for applications such as orientation and tracking for robots, navigation of autonomous transport systems (AGVs), among some of the many possibilities.

"This collaboration enables us to realize the full potential of end-point AI, allowing for actionable insights into manufacturing operations to improve productivity and lower costs," said Christian Verbrugge, GML Europe's senior director business development.

www.framos.de
www.graimatterlabs.ai

Jenoptik acquires Berliner Glas Medical and SwissOptic

Accelerated growth and stronger focus on photonics, expansion: Jenoptik AG has acquired a 100 percent stake in the three companies BG Medical Applications GmbH ('Berliner Glas Medical'), a supplier of high-precision, custom optical components for the medical technology sector based in Berlin, SwissOptic AG, a specialist in the development and manufacture of optical components and assemblies, primarily for the medical technology, semiconductor, and metrology industries headquartered in Heerbrugg, Switzerland, and SwissOptic (Wuhan) Co. Ltd., based in Wuhan, China, together with SwissOptic AG from Berliner Glas GmbH, a wholly-owned subsidiary of ASML Holding NV.

"With this strategic acquisition we will strengthen our global and fast-growing photonics business by significantly expanding our already strong semiconductor equipment business, and in particular our highly attractive medical technology business," says Stefan Traeger, Jenoptik president and CEO.

In 2022, the acquired companies are expected to contribute around € 130 M in revenue. The purchase price amounts to around € 300 M. The contracting parties have agreed not to disclose the exact terms.

Berliner Glas Medical and SwissOptic currently employ around 500 people worldwide. The management will continue to act in its current function for Berliner Glas Medical und SwissOptic under the umbrella of the Jenoptik Group.

www.jenoptik.de

"175 years of innovation, passion and the courage to develop"

On 17 November 1846, young mechanic Carl Zeiss opened his workshop for precision mechanics and optics in Jena, thus laying the foundation for what would become the Zeiss group.

The company ran a celebration event which took place virtually on 16 November 2021 at the Volkshaus, in the company's founding city of Jena. During the virtual event, Karl Lamprecht, president and CEO of the Zeiss group, praised the company's successful past, celebrated its present and shared his outlook on the future.

"Zeiss' unique history and its exceptional achievements make it a truly extraordinary company. Its 175 years also demonstrate the company's high level of resilience and its willingness to accept change. And, above all, Zeiss' tremendous passion, coupled with its pioneering spirit and its pragmatism in challenging and pushing the limits of the technically feasible," said Dr Lamprecht. "175 years of Zeiss motivate us to look ahead and help contribute to a bright future shaped by technological innovations."

To mark its 175th anniversary, Zeiss launched the global initiative "A Heart for Science" to pool its projects to encourage young people to pursue a career in the STEM subjects and to get new activities off the ground.

In a video message, German Federal President Frank-Walter Steinmeier congratulated all Zeiss employees around the world.

Dr Karl Lamprecht (Source: Zeiss)

www.zeiss.de

Nynomic expands technology portfolio

The optical measurement technology group Nynomic has added its tenth member by means of acquiring all shares in MGG Micro-Glühlampen-Gesellschaft Menzel from Possehl Mittelstandsbeteiligungen. The parties agreed on confidentiality regarding the transaction, consisting mainly of shares. 116,700 Nynomic AG ordinary shares will be granted through a non-cash capital increase from authorized capital. As a long-term oriented, strategic investor, Nynomic will manage and develop MGG while maintaining its operational independence.

MGG, based in Wentorf near Hamburg, has been a well-known producer of micro light bulbs for more than fifty years. These are mainly used in optical measurement technology as well as safety and medical technology applications. MGG and Nynomic have been working in a trustful cooperation for years.

The highly profitable company has around twenty employees and annual sales of approximately two and a half million euros. MGG's microincandescent lamps are a modern component for many today's electrical and electronics industries. More than five thousand different types of lamp are produced.

www.nynomic.com
www.mgg-lamps.de

EO to distribute Trumpf lasers

Trumpf Laser Technology has partnered with Edmund Optics (EO) to enhance global access to its TruPulse nano ns-pulsed fiber lasers.

"Edmund Optics is excited to help SPI Lasers rebrand as Trumpf Laser Technology by providing customers with laser components and fast deliveries through EO's global infrastructure" said Ed Kay, EO vice president of retail marketplace.

"We are excited to announce our partnership. EO's technical knowledge of optics, imaging, laser components, and measurement equipment makes them ideal for labs and research groups to source what they need," said Jack Pennuto, director of sales and applications at Trumpf Laser Technology.

The Trumpf TruPulse nano is a nanosecond-pulsed fiber laser that provides great versatility for industrial nanosecond processing. A tunable pulse duration regime from 3 to 2,000 ns provides wide compatibility for many different types of application.

Source: Edmund Optics

Trumpf TruPulse nano

www.edmundoptics.com
www.trumpf.com

Volvo invests in imaging start-up Spectralics from Israel

The Swedish car maker has invested in the optical and imaging technology start-up Spectralics through the company's venture capital arm. The investment gives Volvo Cars access to promising technology at an early stage of development that could contribute to making cars safer and revolutionize in-car user experience.

Coming from a background in aerospace technology development, Spectralics creates state-of-the-art imaging and optical infrastructure spanning materials, hardware and software, enabling a wide variety of advanced optical capabilities.

One of the company's core solutions is the multi-layered thin combiner (MLTC) which is a new type of thin optics 'film' applicable to see-through surfaces of all shapes and sizes. Integrated into a car's windshield or windows, the technology could be used to overlay imagery on the glass.

In a windshield configuration, the technology could create a wide field of view 'heads-up display' that can instill a sense of distance as virtual objects are superimposed onto the real-world environment for a safe and immersive experience.

"Spectralics is an exciting company with technology that holds truly great promise," said Henrik Green, chief product officer at Volvo.

"We identify multiple touch-points with Volvo's vision in the ecosystem and recognize future models as the right fit for new technologies," said Ran Bar-Yosef, co-founder and CEO of Spectralics.

Source: Volvo

Optical technology assists drivers

www.volvocars.com
www.spectralics.com

Trumpf acquires joint venture with Sisma

The German high-tech company is strengthening its additive manufacturing (AM) division: as announced last year, the Ditzingen-based group is taking over the joint venture Trumpf Sisma S.r.l. completely from its Italian partner. Up until now, Trumpf held 55 % of the shares.

Source: Sisma

Steffen Scholz, head of M&A of Trumpf (left), and Marco Salmaso, CEO of Sisma

In addition, Trumpf will continue Sisma's LMF (laser metal fusion) business in the industrial, dental and medical markets. The two companies have now signed an agreement to this effect.

In the context of the sale of the joint venture and its own LMF division, Sisma plans to focus on the jewelry and fashion industry and to distribute LMF machines from Trumpf for these markets.

Trumpf-Sisma was founded as a joint venture in 2014 and is based in Schio in northern Italy. Around sixty employees work there in the development and production of metal 3D printing machines with laser metal fusion technology.

The transaction is expected to be completed by the end of 2021. The two companies did not provide further details.

www.sisma.com
www.trumpf.com

Europe's largest capacity foundry service for PICs created

Clean room (Source: X-Fab)

Ligentec, a provider of high-performance, low-loss, silicon nitride photonic solutions, and specialty semiconductor producer X-Fab Silicon Foundries have announced a strategic partnership resulting in the large-scale supply of integrated photonic devices.

"Silicon nitride offers superior performance to manage the light in the chip circuitry, with unprecedented low propagation losses and high-power handling," states Michael Zervas, co-founder of Ligentec. "While there is growing worldwide demand for silicon nitride PICs, the missing piece is a commercial volume foundry that can keep pace with the expected uptake."

Ligentec has implemented its proprietary, patented, low-loss silicon nitride process technology within X-Fab's existing high-throughput foundry workflow. It means that Ligentec PICs are now commercially available in high volumes out of Europe.

"X-Fab's advanced equipment, superior process control and its multiple sites and capacity to deal with 100,000 new 200 mm wafer starts per month gives exceptional supply assurance and almost limitless scope for scaling. The proven track record X-Fab has in the automotive and medical sectors will open up new opportunities for Ligentec," says Ligentec's director Thomas Hessler.

www.ligentec.com
www.xfab.com

Partnership to address display industry

Source: Trumpf

Left to right: Sven Köhler and Hartmut Heyer (Layertec), Richard Bannmüller, Thomas Harrer, and David Renner (Trumpf)

High-tech company Trumpf has announced a strategic partnership with Layertec, a manufacturer of precision optics, in an agreement that will strengthen the competence they can both bring to the display industry. The alliance will see Trumpf invest in a broad range of machinery for the manufacture of large optical components. Some of this machinery has been acquired from optics specialist Berliner Glas. These large optical components are used in the latest laser systems from Trumpf, which aare specifically designed for the production of OLED displays.

Layertec is based in Mellingen, a town near Jena, and currently has around 330 employees. "This new machinery will enable us to expand our manufacturing operations so that we can produce even larger optics of the kind that Trumpf uses in its systems. Our cooperation is going to intensify, and we both expect it to generate even more synergies in the future," says Hartmut Heyer, managing director of Layertec.

www.trumpf.com
www.layertec.de

AEMtec opens tech center in Boston

The Berlin-based manufacturer of high-precision micro and optoelectronic modules AEMtec opened its Engineering Tech Center within the Boston University Photonics Center on September 1.

The director of the new tech center is Robin Jerratsch, an experienced microelectronics and optics engineer. He explains: "Our goal here in the BU Photonics Center is to form the focus of the most modern product development in the fields of silicon photonics and microelectronics. Here we can better serve our US customers by offering rapid prototyping for product development programs that require wire bonding, flip-chip and precision placement in cleanroom environments."

AEMtec CEO Jan Trommershausen also emphasizes the importance for the US market, "The tech center offers our US-based customers the opportunity to validate their new product designs and then seamlessly transfer the product to our large production facility in Berlin. And where better to open a Tech Center than in the middle of Boston, which is known for its scientific and technological developments?"

As an established B2B company for complex and reliable solutions, AEMtec is a strategic partner for the manufacture of microelectronic and silicon photonic modules in the medical technology, industrial manufacturing, semiconductor and aerospace industries.

www.aemtec.com

Cooperation of TEKA and JustLasers

The German-based TEKA Absaug- und Entsorgungstechnologie GmbH has been one of the leading manufacturers of extraction and filter units for the industry, commerce, craft enterprises and laboratories in Europe for 25 years. They have started a cooperation with JustLaser, a family-owned company in Thalheim near Wels in Upper Austria.
The company went to market in the middle of the 2020 spring lockdown and specializes in laser systems that can be used to engrave, cut and mark a wide variety of materials such as metals, wood, acrylics, plastics or textiles in a wide range of commercial and industrial applications.
TEKA will now make its complete product portfolio available under the 'JustAir' brand of its business partner. The coordinated units safely and reliably extract the smoke and fumes produced during laser processing.
TEKA has made all the adjustments required to ensure the trouble-free interaction of laser and extraction units, for example to the interfaces between them.

The JustLaser 7.5 with JustAir Pro has become a much sought-after combination solution over the past year. (Source: Teka)

www.teka.eu
www.justlaser.com

Intel launches Integrated Photonics Research Center

The Intel Research Center for Integrated Photonics for Data Center Interconnects was recently opened by Intel Labs. The center's mission is to accelerate optical input/output (I/O) technology innovation in performance scaling and integration with a specific focus on photonics technology and devices, CMOS circuits and link architecture, as well as package integration and fiber coupling.

The ever-increasing movement of data from server to server is taxing the capabilities of today's network infrastructure. The industry is quickly approaching the practical limits of electrical I/O performance. As demand continues to increase, electrical I/O power-performance scaling is not keeping pace and will soon limit available power for compute operations. This performance barrier can be overcome by integrating compute silicon and optical I/O, a key research center focus.

"At Intel Labs, we're strong believers that no one organization can successfully turn all the requisite innovations into research reality. By collaborating with some of the top scientific minds from across the US, Intel is opening the doors for the advancement of integrated photonics for the next generation of compute interconnect. We look forward to exploring how we can overcome impending performance barriers," explains James Jaussi, senior principal engineer and director of the PHY Research Lab in Intel Labs.

www.intel.com

Smart Factory Institute opened, Senswork is inaugural tech partner

The new Smart Factory Institute a private/public partnership in partnership and collaboration with the Volkswagen Academy in Chattanooga, Tennessee, will enable manufacturers access to the most advanced production technologies available and will help ease the transition of these technologies to the manufacturing workforce.

Senswork from Germany just opened its subsidiary in Johnson City, Tennessee, to support their clients in North America. Senswork Inc. has become the inaugural technology partner of the institute and plans to install a demo vision system. This will create an experimental display for manufacturers to test its capability and to train employees. Ryan Lilly, president, Senswork Inc, said, "Given the rapid pace of technological development in the automation industry, it is imperative to stay on the edge of innovation. Hardware and software must be precisely designed, developed, and coordinated. Solving the most complex inspection challenges to guarantee quality assurance where a zero-error rate is essential, is what drives us."

Source: Deutsche Messe

The Smart Factory Institute Chattanooga opening

www.senswork.com
www.senswork.us

Cirdan launches certificate facilitating investment in the world's first photonics index

With collaboration from C8 Technologies, Cirdan Capital Management has launched a certificate based on the Solactive EPIC Core Photonics Index (cf. p. 24). The certificate will be listed on the Frankfurt Stock Exchange for retail and institutional investors with the ISIN Code XS2412871902 and an initial value of 1,000 euros per certificate, available Christmas 2021, through brokers and on the C8 Technologies platform.

The Solactive EPIC Core Photonics Index is the first of its kind to represent a global cross-section of the world's largest and most liquid public photonics manufacturers and includes all companies with at least fifty percent of their revenues sourced from photonics manufacturing activities. This means that for the first time, investors will be able to specifically target their investments to the photonics industry.

The photonics industry is expected to grow by more than 13 % annually with a total market value in excess of one trillion dollars by 2026. Over the last six years, the back-tested index outperformed MSCI World by 15 % per year with a similar level of risk (volatility).

Following the launch, EPIC will be actively looking at how pension funds can avail themselves of this new, greener investment. Half of the certificate revenues will be reinvested into promoting photonics globally.

Pierre-Antoine Llinas from Solactive and Carlos Lee from EPIC (Source: EPIC)

www.epic-assoc.com

Purmundus Challenge presented for the ninth time

The annual international design competition for 3D and 4D printing was concluded in Frankfurt on 18 November 2021 as part of the Formnext exhibition. A total of eight submissions received the coveted gold trophies.

Sophia Lindner from act'ble won the first prize of the Purmundus Challenge-with the innovative development 'New Pointe Shoe Sole'. Second prize went to Ramon Mañas, Odisei Music SL, for 'Travel Sax', while Jamie Cook, Henry Neilson, Theo Clarkes, Mark Brown, Jess Lewis, and George Jary of HEXR won third prize with their 3D-printed custom-fitting bicycle helmet.

Special awards were also presented, among them the 'Special Mention' to Dr Myriam Lingg, Lukas Schiller and Alec Chevrot (macu4 AG) for their Macu4 Forearm Prosthetics – breathable and customized prostheses for the forearm.

Source: Mesago, M. Kutt

Formnext 2021 Purmundus Challenge winners

www.purmundus-challenge.com

"Biggest development in semiconductor lasers in 30 years"

The Vector Photonics team has won the Royal Academy of Engineering Colin Campbell Mitchell award for "the greatest contribution to the advancement of any field of engineering in past four years." Previous winners of the UK-based award include Oxehealth for its non-contact health monitoring, and Optical Networks Group for advancements in optical communications.

(l to r) Prof Richard Hogg, Dr David Childs, Dr Richard Taylor (Source: Vector Photonics)

The University of Glasgow spin-off, comprising Dr Richard Taylor, Dr David Childs and Prof Richard Hogg, received the award for the photonic crystal surface emitting laser (PCSEL), a low-cost, high speed, high power, surface emitting laser. "It's the biggest development in semiconductor lasers in thirty years," said Prof Steve Beaumont, OBE, vice-principal for research and enterprise at the University of Glasgow, who nominated them for the award.

The team is now commercializing the technology, which was initially focused on datacoms but is beneficial to multiple semiconductor applications.

www.vectorphotonics.co.uk

A celebration of brilliant leadership


Source: EPIC

Torsten Vahrenkamp, CEO of Ficontec (right) is honored with the EPIC CEO Award 2021 by Jose Pozo.

The European Photonics Industry Consortium has presented the EPIC CEO Award 2021 to Torsten Vahrenkamp, CEO and co-founder of Ficontec. After co-founding the company together with Matthias Trinker (CFO), and following a very difficult start due to the telecom bubble roughly twenty years ago, Ficontec's expansion over the last decade has been impressive. The company's workforce has grown from twenty five to around two hundred since 2010, the production facilities have been increased from 1,000 to 4,000 m^2, subsidiaries have been opened in China, Thailand, and the US, and a system design and production plant has been established in Estonia.

According to EPIC's CTO, Jose Pozo, Ficontec has revolutionized the way that industry approaches photonic device manufacturing worldwide.

www.epic-assoc.com
www.ficontec.com

In memoriam Valentin Gapontsev

Valentin P. Gapontsev, PhD, was an accomplished entrepreneur in addition to being a recognized scientist and inventor. He passed away on October 22nd, after reportedly having battled cancer.

Dr Gapontsev had over forty years of experience in the field of non-radiative energy transfer in rare earth ions and solid-state materials. With this scientific background, he predicted an effective high power fiber laser when fiber lasers had output powers of just a few watts. In his 1990 paper discussing the theoretical feasibility of a high-power fiber laser with kilowatt-scale average output power, he set in motion his quest and mission to develop fiber lasers to be more reliable and cost-effective. He is widely credited with having created the fiber laser industry by manufacturing reliable, cost-effective and higher power solid-state lasers that can be used in a growing number of applications.

Gapontsev was educated at the Lviv Polytechnic Institute and the Moscow Institute of Physics and Technology, and received a PhD. From 1967 until the early 1990s, he worked at the Soviet Academy of Science as senior scientist in laser material physics and laboratory head.

He founded IPG in 1990 – the company now employs over 6,000 staff – and in 2020 Forbes magazine ranked him among the 400 richest persons in America.


Source: IPG

Dr Valentin Gapontsev
1939 – 2021

www.ipgphotonics.com

Klaus Fiedler named as LPKF's new Chief Executive Officer

The supervisory board of LPKF Laser & Electronics AG has appointed a top manager with a three-year term: Dr Klaus Fiedler will become the new CEO. The supervisory board of the SDAX-listed technology company has appointed the 50-year-old to join CFO Christian Witt on the management board, effective 1 April 2022.

Source: LPKF

Dr Klaus Fiedler

"With his deep understanding of the tech space, strong customer focus and deep understanding of the relevant markets in Asia-Pacific, North America and Europe, LPKF will greatly benefit from his entrepreneurial spirit and ability to engage with global Tier-1 customers," says Jean-Michel Richard, chairman of the supervisory board.

Klaus Fiedler has a PhD in physics and is currently vice president and head of corporate ventures at Schott. Before that, he served in various senior management positions at Knowles Electronic in China, at NXP in Austria and at Philips Research in the US and in Germany.

As planned, interim management board member Britta Schulz will leave the board after Fiedler joins and return to her role as managing director of the development business unit.

www.lpkf.com

EO introduces new SVP Technology and Development

Edmund Optics (EO) appointed Dr Ekaterina 'Katya' Golovchenko as senior vice president of technology and development. This newly created position is part of a series of aggressive technology-related investments aimed at delivering greater optical innovation to meet the demands of an increasingly complex market.

Source: EO

Dr Ekaterina Golovchenko

In her new role, Katya will be responsible for expanding and enhancing Edmund Optics' Research and Development and Engineering groups. She will work to ensure the company's technical resources and developments are well synchronized with product and manufacturing roadmaps to speed up innovational efforts. Katya will also chair an internal technology and advisory committee, a team that prioritizes and oversees EO's technology development activities.

Katya received her PhD in physics from the Russian Academy of Sciences and was an Assistant Research Professor at the University of Maryland. She has had an impressive career at AT&T Bell Labs, IPG Photonics, and most recently at Lumentum. Katya also serves as a director-at-large for Optica.

www.edmundoptics.com

Macnica ATD Europe introduces new CEO

On the occasion of Vision 2021 trade fair in Stuttgart, Macnica ATD Europe officially introduced Mr Shoichi Teshiba as the new CEO of all European Macnica operations.

Source: Macnica

Shoichi Teshiba

Teshiba, who has been leading the former entities Macnica GmbH and ATD Electronique which became Macnica ATD Europe, is a long-term member of the executive management team from the parent company.

"It is a great pleasure to follow in the footsteps of Antoine Hide who founded ATD Electronique more than three decades ago. On behalf of the entire Macnica team I can assure all ATD partners and customers continuity in business culture and strategy", said Shoichi Teshiba. "Even despite all restrictions caused by the pandemic in the past months, both Macnica and ATD members have formed a team in a unique effort of merging all operations."

Antoine Hide, founder and former CEO of ATD Electronique which he sold to Macnica Inc., will serve Macnica ATD Europe in a consulting position for a transition period. "In Macnica Inc, I found the perfect partner to integrate my former company since we share the same values. Under the exceptional challenges we have all been facing in the last 18 months I decided to extend my consulting role to assist with the few remaining tasks of the integration process."

www.macnica-atd-europe.com

Single frequency lasers

Manufacturer: Nano Scan Technology.
Distribution: Frankfurt Laser Company.
Product: Single frequency lasers of the "NSTL" series with digital control of the radiation power and temperature of the laser diode. Available Models are "NSTL-405" (wavelength 405 nm, line width 0.1 pm, power 20 mW), "NSTL-533" (533 nm, 50 pm, 50 mW), "NSTL-633" (633 nm, 0.03 pm, 50m W), and "NSTL-785" (785 nm, 0.02 pm, 100 mW).

Features: The digital feedback system for the power control uses a microcontroller and a controlled current source, as well as a feedback photodiode, which receives part of the optical radiation through a splitting prism. The temperature control of the laser diode is using a peltier element, a temperature sensor, a controlled current source and a microcontroller. Thus, digital feedback is also used to control the temperature. The laser contains a number of optical elements for filtering and polarizing laser radiation. The laser beam from the diode passes through a collimation lens, a Bragg grating, which provides high-quality properties of single-mode and narrow line width, a polarizer, a splitting prism to ensure constant power feedback, and an optical isolator that prevents reflected laser radiation from entering the feedback system.
The laser is controlled via a PC via a USB interface. Using the installed software, the desired power and temperature of the laser diode are set, as well as monitored in real time.
Applications in industry metrology (holography, interferometry, LIDAR, spectroscopy, Raman spectroscopy, velocity laser measurement, semiconductor control), biomedical investigations (opto acoustics, photo acoustics, optical genetics, microdessection, Maldi-TOF, flow cytometry, DNA sequencing), and optical research (cold atoms and molecules, lithography, nano photonics, quantum electronics, single molecule detection, dynamic light scattering, fluorescence microscopy).

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Single-mode VCSELs at 760 nm and 763 nm

Manufacturer: Frankfurt Laser Company.
Product: New single-mode VCSELs "FLPD-760-0.25-VCSEL-TO39" and "FLPD-763-0.25-VCSEL-TO39" at wavelength 760 nm or 763 nm, respectively, with a wide tuning range of 2 nm.
Featurs: The 3dB modulation bandwidth is better than 0.1 GHz. The Lasers are supplied for TDLAS applications, i.e. oxygen detection. The VCSELs come in TO39 housing with integrated TEC, thermistor and ESD protection. Additional they are equipped with an AR-coated and declined protection window.

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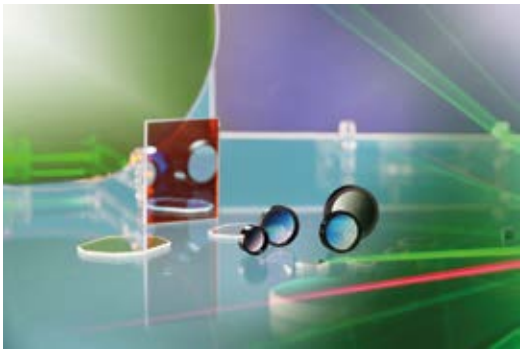
Laser-specific optical filters in special sizes

Distribution: AHF analysentechnik.
Product: Optical filters in a wide variety of imaging and laser systems that are used in industry and science to precisely suppress unwanted signals or wavelengths.
Features: The requirements are quite diverse, not only regarding the spectral properties, but also in the size and shape of the filters. These range from very small filters (e.g. 2 × 4 mm edge length or 3 mm diameter) to filters with large dimensions (e.g. 280 × 280 mm). The optical filters are, on the one hand, tuned to specific laser wavelengths and, on the other hand, tailored to the customer's needs in regard to size and shape. The hard-coated filters are extremely robust, insensitive to moisture, have very low absorption, do not influence the beam profile of the laser and show almost no shift of the central wavelength (a few pm/K) when the temperature changes. Transmittance levels up to 98 % and blocking levels up to OD6 ensure effective filtering of the desired wavelength range.
Due to many years of cooperation with various renowned filter manufacturers, AHF can offer the most suitable filter equipment for the customer's optical system. It is possible to manufacture small quantities as well as large quantities, e.g. for OEM customers.



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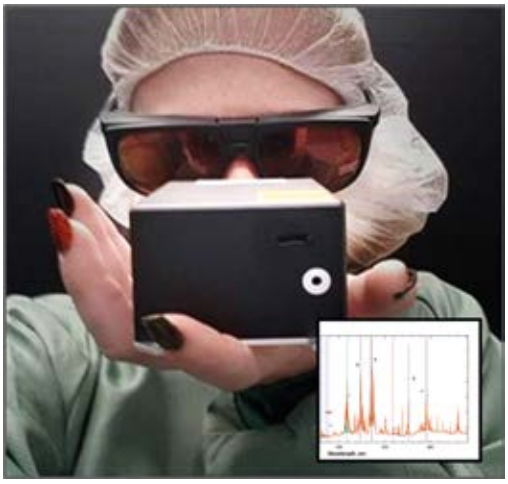
New wavelength for high performance Q-switched lasers



Manufacturer: Hübner Photonics.
Product: New model in the "Cobolt Tor" Series of high-performance, compact, air-cooled Q-switched lasers. The "Cobolt Tor XE 532 nm" delivers 0.25 mJ per pulse at up to 1 kHz repetition rate in a compact laser head which contains all drive electronics.
Features: Using the sophisticated laser cavity design characteristic to the series, the new model delivers a unique combination of compact size and performance: kHz repetition rates, short pulse lengths (1–3 ns) and excellent pulse-to-pulse stability (jitter < 2 µs) for a passively Q-switched laser in a TEM_{00} beam. Through advanced and fully integrated control electronics the emission can be triggered from single pulses up to 1 kHz pulse trains or bursts of pulses using external or internal trigger signals, or a combination of both.
The lasers are manufactured using proprietary "HTCure" technology in a compact and hermetically sealed package, which provides a very high level of immunity to varying environmental conditions and exceptional reliability. Lasers built using this technology have shown to withstand multiple 60 G mechanical shocks in operation without any sign of degraded performance. They can be exposed to extreme temperatures (>100 °C) and are insensitive to pressure and humidity.
Applications: The laser line is intended for integration into instruments for marking, laser induced breakdown spectroscopy (LIBS), LiDAR as well as photoacoustic microscopy applications.

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Portrait of JPT Opto-electronics

The chinese company *JPT Opto-electronics,* registered in 2006, focuses on R&D, production, sales and service for laser and optical connectors.
Based on the leading laser technology, the company offers various products, including MOPA pulsed fiber laser, CW fiber laser, QCW fiber laser, DPSS laser, Pico Lasers, etc.
The "MOPA" pulsed fiber lasers source has an output power from 20 W up to 350 W, suitable for different laser applications, such as scribbling, drilling, sheet metal cutting, welding, metal surface processing, peeling coating, surface treatment and marking on fly.

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Frequency-converted tunable diode laser vom deep UV to NIR

Manufacturer: TOPTICA.
Product: High-power, tunable, frequency-doubled or quadrupled diode lasers "TA-SHG pro" and "TA-FHG pro" for the spectral range from 205 to 780 nm with an output power up to 20 W. The systems are fully integrated and excel in a high passive stability as well as a convenient remote operation.
Background: Nonlinear frequency conversion techniques access wavelengths that cannot be generated directly from laser diode technology. Via second or fourth harmonic generation, *TOPTICA* laser systems can access the UV, blue, green, yellow and orange spectral ranges at high powers.
Features: The "TA-SHG pro" system, part of the UV/RGB solutions, comprises a tunable diode laser, a high power semiconductor (TA) and an integrated frequency doubling stage (SHG pro). Alternatively, it is available with a fiber (FA) or Raman fiber (RFA) amplifier. The SHG stage is a folded ring cavity in bow-tie configuration with excellent thermal and mechanical stability.
The "TA-FHG pro" is a tunable, diode-based laser source in the deep UV spectral range. The system consists of an additional SHG stage compared to the "TA-SHG pro" system. Alternatively, it is also available with a fiber (FA) or Raman fiber (RFA) amplifier. For optimization of Deep UV power and lifetime, it can be equipped with the SUV cavity.
The systems now include fully-automated push-button coupling optimization into the TA chip, the SHG cavity and the output fiber, as well as output power stabilization. They provide tunable laser radiation for spectroscopy, laser cooling, optical data storage, holography and interferometry.

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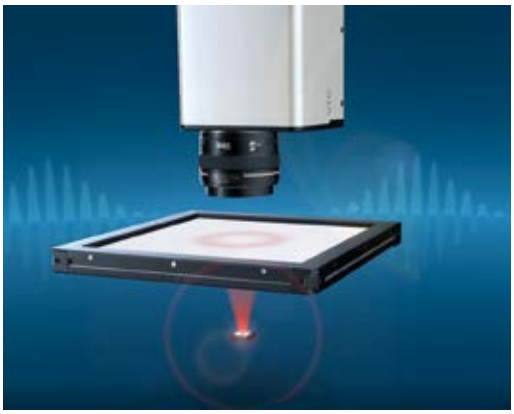
Laser safety for 3D sensor applications

Manufacturer: Instrument Systems.
Product: Practicable concept for laser safe viewing of VCSELs that conforms to the international laser safety standard IEC60825-1. It is based on a laser class assessment chart and modular test system that is absolutely calibrated, and delivered with a test certificate for the error budget.



Features: The two main modules of the test system are the pulsed VCSEL tester "PVT 100/110" and the camera-based "VTC 2400". The tester is a custom solution for the control and measurement of nanosecond pulses as used for LiDAR or time-of-flight applications. Typical measurement parameters are wavelength, repeat frequency, pulse width, pulse energy or pulse sequence. It offers a high spectral resolution (≥ 0.12 nm), extremely short pulse sequences up to 1 ns at high currents as well as test pulse sequences with a repeat rate of more than 100 MHz. The camera-based "VTC 2400" enables far-field analysis of the spatial radiation properties of VCSEL arrays. Typical measurement parameters are average power, beam profile, highest intensity spot and angle of divergence (for the spot area). Using the laser class assessment chart, all critical parameters are identified in a few steps, e. g. beam divergence, pulse length or duty cycle, with a minimum absolute error budget. This enables the full performance efficiency of the VCSELs to be exploited while assuring safe operation.

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SPIE Photonics West, Booth 4013

Wide beam imager for measuring large and divergent beams of SWIR wavelengths

Manufacturer: Ophir Spiricon.
Distribution: MKS Instruments.
Product: Compact, calibrated optical system "Ophir Wide Beam Imager SWIR" (WB-I SWIR) for measuring the size and power distribution of large and divergent beams of VCSELs and LEDs in the short-wave IR range (900 to 1700 nm).
Features: Current methods of profiling wide and divergent SWIR wavelength beams provide inaccurate results due to the high angle dependence of the sensor, or require bulky and expensive laboratory equipment that is not suitable for field operation or production environments. The new system, when combined with "BeamGage" software and an InGaAs camera, is capable of imaging any beam shape (round, line, square, or doughnut) that is too large for a camera sensor. It features a 45 mm diameter aperture and can accurately measure beams with an angle of incidence up to 70 degrees (compare with 15 degrees for standard beam profilers). Beams are captured on a translucent diffusive screen and then re-imaged to produce a complete and accurate mapping of the light's intensity distribution.
Applications: The profiler is designed for use with camera-based beam profiling systems in such areas as eye-safe applications using IR VCSELs or diodes, automotive LIDAR, facial and gesture recognition, and remote sensing.

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Fiber coupler with super fine-focussing mechanism

Manufacturer: Schäfter+Kirchhoff.
Product: Fiber Collimators "60FC-SF" series with super-fine thread, an improved, advanced version of the series "60FC-F" series collimators, providing an even more precise focus setting. They can be used as collimators for laser radiation from a single-mode fiber and also as fiber couplers with high pointing stability.
Features: The easy, highly defined and improved adjustment of the focal setting ensures high coupling efficiencies even when the divergence or the wavelength of the laser source used varies.
The distance between fiber end-face and collimating optics is adjusted using

a threaded ring with a super-fine thread with 0.35 mm pitch. The improved mechanics lead to an increased pointing stability and reduced backlash during the focus setting. The lens in these fiber collimators is spring-loaded. The linear bearing ensures that the lens does not rotate when adjusting the focus.
The new fiber couplers are available with several focal lengths and a variety of AR coatings with paraxial (FC-PC) or inclined coupling axis (FC-APC).

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Large aperture and high resolution beam profiler

Manufacturer: Duma Optronics.
Product: New beam profiling sensor "BeamOn HR 1"". This revolutionary beam profiling camera features a 1" detector with 20 MP resolution for better serving the Photonics industry, with some focus in automatic testing of VCSELs and multiple beams analysis capability. It was recently introduced to support new lasers and VCSEL chip components.

Features: This classical camera look-alike beam profiler is a GT interface camera with a large spectral response from deep UV to 1350 nm and beyond. Due to its relatively small pixel size of 2.4 × 2.4 µm, it offers a large beam size measurement over a wide spectral range from ø 30 µm to ø 8 mm, with 16 bit digital depth and independent gain and shutter control. This feature allows intricate measurements replacing different beam profilers which are currently available in the market into one system.
Applications: The new device is designed for the use in the photonics and laser industry.

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Web: www.dumaoptronics.com

Laser beam diagnostics of green high-density laser beams

Manufacturer: PRIMES.
Product: Easy-to-use laser beam diagnostic system "FocusMonitor FM+ HDP" for the caustic analysis and diagnostics of laser sources in the green spectral range.
Features: Through continuous development and the special design of the new measuring principle "FS3" (Fused Silica Sensor System), it is now possible to measure the power density distribution of laser beams with very high power densities of up to 50 MW/cm^2. Beam diameters of 100 µm up to 1200 µm can be evaluated. The new device is available for beam sources in the wavelength range of 515 to 545 nm and 1.0 to 1.1 µm. Together with the powerful "LDS LaserDiagnosticsSoftware", the user gets a versatile laser diagnostics system with a convenient operation, providing highly reliable measurement results.
Applications: The system allows the caustic analysis of laser beams in previously difficult to evaluate power ranges, which find use, for example, in remote welding applications or the processing of copper.

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Large asphere with up to 200 mm diameter

Manufacturer: Edmund Optics.
Product: "Techspec" precision aspheric lenses with a diameter up to 200 mm.
Background: The recent drive towards

higher power lasers in optical applications has been pushing the limits of optical coating technology. An alternate solution for handling higher power beams is to increase beam diameter, requiring larger optical components. Larger beams decrease the energy density spread across optical components, reducing the likelihood of laser-induced damage. In this scenario, and numerous others, the performance of the optical system can be further increased by using aspheric lenses instead of spherical ones.
Previously, optical designers may have had reservations about using aspheric lenses with diameters exceeding 100 mm due to the difficulty of making and measuring aspheres that large. However, recent advances in the fabrication and metrology of aspheric surfaces have allowed aspheres as large as 200 mm in diameter to be commercially available.
Features: The precision aspheres are manufactured using state-of-the-art production and metrology equipment. Alongside their large inventory of standard lenses and assemblies available in quantities large and small, the company can utilize their engineering expertise to offer fully customized designs. Capabilities range from commercial to high precision specs including <0.06 µm PV Asphere Figure error, 0.5 arcmin beam deviation, 10^{-5} scratch-dig, various coating options (UV, VIS and IR) and more.

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Miniature slides

Manufacturer: PM B.V.
Product: Miniature slide "MSR 3", the smallest linear slide available in the industry. It is designed for the optical and medical industry where precise movements are required, often within very tight installation spaces. The design offers very smooth motion and high repeatability.
Features: With a height of only 3.2 mm and a width of 5.5 mm, the slide offers maximum space savings. It provides the advantages of cross roller bearings together with anti-cage creep technology. The slide is free of play and preloading is done at the factory by matching the rollers in tolerances of 0.1 µm to the raceways.
The slide top and base have equal lengths. The slide comes in for lengths (8, 15, 20, and 25 mm) with stroke lengths of 5 to 20 mm. The dynamic load rating is ranging from 191 N to 393 N. The

slides are 100 % made of stainless steel. Crossed roller design offers high stiffness and precision. The devices are factory preloaded, ready-to-install, and can be used in every mounting orientation. The miniature slides can be customized as many applications have specific needs, e.g. specific pushing force, specific table part design, additional holes or clean-room and vacuum compatible.—
The whole "MSR" range include 7 sizes and covers over 30 lengths. The stroke ranges from 5 to 112 mm and dynamic load carry capacity starting at 191 till 7819 N.

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3D microscopy of human organs

Looking at specific cell types with micrometer precision

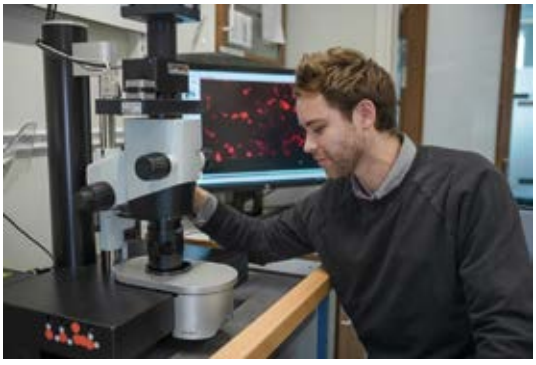
A new method can be used to reveal previously unrecognized alterations in the pancreas, but it can also be used to study other human organs and diseases.

What the researchers have done is to divide the organs by the use of a 3D-printed matrix, creating portions of tissue with the optimal size for optical imaging using 3D technology. These pieces can then be labelled to visualize essentially any cell type or protein of choice. Since each bit of tissue has known coordinates, the individual 3D images can be pieced together using a computer into a three-dimensional jigsaw puzzle to form an intact human organ. This method makes it possible to create high-resolution 3D images of human organs in practically any size, with maintained micrometer precision.

Previously, it has been possible to create high-resolution images of biological material with the use of technology such as optical projection tomography and light sheet fluorescence microscopy, which is something the researchers have used also in this study. The problem, however, has been that previous methods have offered no usable way of labelling the various cell types or proteins being studied, by using fluorescent antibodies for instance, when analyzing a larger specimen such as an entire organ. This is the problem that the new method has now solved.

The Umeå researchers have used the method to study the human pancreas. Inside the pancreas there are hundreds of thousands of insulin-producing cells, the Islets of Langerhans. These islets have a key function in the production of insulin and are therefore important to diabetes when the production is disturbed. Using this new method, the researchers are able to demonstrate previously unrecognized features of the human pancreatic anatomy and pathology, including areas with extremely high islet density. Their results may have implications for anything from preclinical to clinical areas, for instance to improve islet transplantation protocols for people with diabetes, or when developing non-invasive clinical imaging to study the pancreas in people with diabetes.

"Beside using the new method to study diabetes, it can also improve the understanding of other pancreatic diseases, not least pancreatic cancers, and we have initiated collaborations with clinical researchers to look into that. But it should be possible to use the technology itself to study other organs and diseases in similar ways since it enables the study of where cellular changes take place in a full organ context, their amount and relationship to nearby tissues and cell types," says Umeå professor Ulf Ahlgren.



Max Hahn, doctoral student at Umeå Center for Molecular Biology, studies a tissue sample with a light sheet fluorescence microscope. (Source: M. Pettersson)

Reference: *M. Hahn* et al.: 3D imaging of human organs with micrometer resolution - applied to the endocrine pancreas, Commun. Biol. **4**, 1063 (2021); DOI: 10.1038/s42003-021-02589-x

www.umu.se

A fiber-to-SiPh PIC coupling solution

Optoscribe is now sampling its monolithic glass chip for low-loss coupling to silicon photonics (SiPh) grating couplers

Created using the company's proprietary high-speed laser writing technique, the solution is designed to overcome fiber-to-SiPh photonic integrated circuit (PIC) coupling challenges to enable high volume automated assembly and to help drive down costs. Optoscribe's OptoCplrLT uses low-loss light turning curved mirrors, which are formed in the glass, to direct the light to or from the SiPh grating couplers. This removes the need for bend-tolerant fiber solutions, which are often expensive, challenging to manufacture and have some significant limitations in size and profile.

OptoCplrLT has a low-profile interface, ~1 mm device height and ~1.5 mm with cap, which allows compact interface layouts that alleviate packaging constraints and helps address footprint challenges. The solution is also compatible with industry-standard materials and processes; for example, the glass chip has a coefficient of thermal expansion matched to the silicon chip, helping to maximize performance.

Russell Childs, CEO of Optoscribe, said "We are pleased to announce that we are now sampling OptoCplrLT, which offers data center operators, transceiver manufacturers, and optical component suppliers an innovative solution to help address fiber-to-SiPh PIC coupling challenges and to help overcome SiPh transceiver packaging and integration hurdles, while meeting market demands of performance, cost and volume."

www.optoscribe.com

OptoCplrLT with fiber assembly, coupling to SiPh grating couplers (Source: Optoscribe)

First commercial UV-plus-visible hyperspectral camera

Unique instrument allows new investigations into ultraviolet research

Resonon has released the Pika NUV2, the only ultraviolet plus visible hyperspectral camera available commercially. It will be an essential tool for advanced research, industrial vision systems, remote sensing, and many other hyperspectral imaging applications.

The Pika NUV2 is a line scan imaging spectrometer that scans a spectral range of 330 – 800 nm. It can be used in Resonon's benchtop, outdoor, airborne, and machine vision systems.

Pika NUV2 ultraviolet-plus-visible hyperspectral camera (Source: Resonon)

Flowers and plants often have noteworthy ultraviolet features, and solar illumination extends down to about 300 nm at the Earth's surface. Furthermore, pharmaceuticals and other industrial products can possess unique ultraviolet signatures which the NUV2 can quantify for sorting or quality control purposes.

"This is a unique product that will enable a whole new field of research in imaging spectroscopy," says Rand Swanson, CEO of Resonon. "We are really excited to see the research and applications that this imager enables our customers to pursue."

Most glass materials that comprise optical lenses do not transmit light below about 350 nm. "This made designing the Pika NUV2 a very difficult optical problem," says Mike Kehoe, chief optical engineer for Resonon. "Nonlinear dispersion indices make distortion control very challenging. We had to develop advanced design and fabrication methods to allow us to successfully overcome these issues. We improved a lot upon our older ultraviolet models. The end result is an optical train that provides excellent imaging and spectroscopic quality."

Over a spectral range of 330 – 800 nm the Pika NUV2 provides 255 contiguous spectral channels at each pixel, and each of these channels is 1.84 nm wide. The spectral resolution (FWHM) is 3.2 nm. Each camera frame is an image line that has 1500 spatial pixels.

https://resonon.com

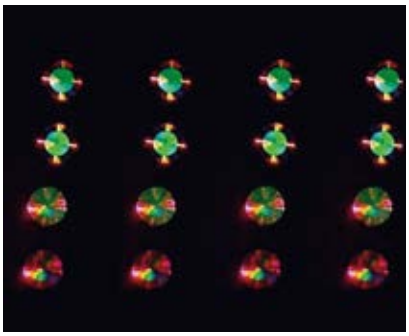
Metalens with extremely high efficiency

Disruptive technology ready for launch, mass production

NIL Technology (NILT) has designed, built, and characterized multiple meta optical element (MOE) lenses with a breakthrough performance of 94 % absolute efficiency.

The result has been demonstrated with a 940 nm NIR lens and the result is regarded as a milestone for the commercial use of metalenses. NILT's MOEs are supposedly the first flat lenses that can compete with refractive optics. The high efficiency makes these lenses ideal for sensing and machine vision applications targeting consumer electronics, industrial, IoT, medical, and automotive markets. These innovative markets will benefit largely from NILT's MOE optical solutions where requirements call for high efficiency, excellent performance, lightweight, and compact designs.

The groundbreaking results show that MOEs have enormous potential. MOEs can disrupt numerous applications, such as simplified time-of-flight (ToF) systems with high relative illumination or ultra-compact NIR cameras used for eye-tracking and driver monitoring. Previously, the main barrier has been the low efficiency of manufactured metalenses. This barrier might now finally be removed.



NILT meta optical elements (MOEs) demonstrating the groundbreaking result of 94 % absolute efficiency (Source: NILT)

"I am happy to share our achievements. We have extensively designed, optimized, fabricated, and characterized MOE lenses with an extremely high absolute efficiency of 94 %. This is proof that high efficiencies of MOE lenses are not only theoretical but can be developed for advanced optical functions, with performance beyond what is possible with refractive optics", says Ulrich Quaade, head of optics at NILT.

Theodor Nielsen, CEO and founder, continues, "Our results show that we have unique design capabilities. Prototyping is secured by e-beam lithography (EBL) and mass production by nanoimprint lithography (NIL). This enables us to rapidly prototype MOEs and scale to mass production faster than anyone else".

MOEs from NILT are ready to be delivered and mass-produced to customers' specifications. They can be designed with complex phase functions, and multi-MOE stacked components can be designed to meet required specifications. The MOE itself is made in silicon on a glass substrate, making it strong, rigid, reliable, and thermally stable. It can be customized for wavelengths in NIR and SWIR bands.

The entire process of MOE production, from design, prototyping, assembling, and mass production is done internally. Mass production is done by NIL, which, unlike semiconductor processes, imposes no restrictions on meta-atom geometries like size, shape, and location. This ensures best-performing MOEs based on current design techniques and greater freedom to innovate. Moreover, NIL enables the company to mass produce without being dependent on capital-intensive equipment and availability of DUV lithography equipment.

www.nilt.com

Advanced efficiency and process control of AM systems

Optics Load Balancing solution maximizes the benefit of having two lasers on the same machine

Prima Additive, a business unit of the Prima Industrie group, Borsa Italiana, and Materialise, a global provider of 3D printing solutions, are intensifying their collaboration in the optimization of metal additive manufacturing systems.

The collaboration between the two companies has led to the optimization of the Print Genius 150, the additive manufacturing system by Prima Additive with powder bed fusion technology featuring two lasers working on the same area. On this machine, Prima Additive has integrated Materialise's MCP (Materialise Control Platform) hardware control to obtain real-time control functions and a streamlined combination with external systems to assist the process, such as monitoring and control systems.

A major result of the integration between the companies is the development of a laser workload balancing algorithm that allows the two lasers to be exploited to the maximum. Thanks to this algorithm, the two lasers are able to work in each layer for the same amount of time, automatically distributing the work in a homogeneous way and eliminating the moments in which only one of the two lasers is at work, maximizing the benefit of having two lasers on the same machine. The first Print Genius 150 resulting from this collaboration was installed at the University of Leuven, Belgium, in April 2021.

'Born from powder' (Source: Prima Additive)


3D printing machine software interface (Source: Prima Additive)

"After the successful integration of our state-of-the-art Machine Control Platform (MCP) into the Print Genius 150, we demonstrated together that our Optics Load Balancing solution ensures an important gain in printing efficiency without loss of print quality. It was also nice to see how the teams – however being located at different sites during Covid-19 travel restrictions – succeeded in delivering such a successful project in such a short time period. The companies form a strong complementary partnership and we are looking forward to further joint projects with Prima Additive," declares Jan Van Espen, research manager at Materialise.

"This first joint project between Prima Additive and Materialise is the first brick of a research and business partnership for the two companies. It will continue to invest in an ever more profitable technological collaboration for the development of increasingly capable and easy-to-use machines, with the target of making additive technology more usable for SMEs and for all the companies that want to integrate this technology profitably into their production contexts," comments Paolo Calefati, head of additive manufacturing and innovation at Prima Industrie.

www.primaadditive.com
www.materialise.com

FDA clears world's first photon-counting CT

'First new major technological improvement for computed tomography imaging in nearly a decade'

Siemens Healthineers has received the Food and Drug Administration (FDA) 510 (k) clearance of the Naeotom Alpha, the world's first photon-counting computer tomograph. With a novel system concept and pioneering new detector technology, it ushers in a new era in computed tomography, a technology that determines the course of many medical decisions.

Source: Deutscher Zukunftspreis / A. Pudenz

MTA in the control room during a CT scan

Thanks to the revolutionary images provided by photon-counting CTs, more people all over the world will benefit from precise and comprehensive examinations at a low radiation and contrast dose – from oncological procedures and heart diagnostics to lung follow-up checks for respiratory illnesses.

The centerpiece of this innovation is the new photon-counting detector whose active detection layer consists of a cadmium telluride one crystal (CdTe) and offers clear advantages over conventional CT detectors. Standard CT detectors convert the X-rays in a two-step process first into visible light that is subsequently detected by a light sensor, ultimately producing the final image. Due to this intermediate step, important information about the energy of the X-rays is lost and no longer available to aid in diagnosis; contrast is reduced, and images lack clarity. The photon-counting CT detector developed by Siemens Healthineers no longer converts the X-rays into visible light. The X-ray photons are converted directly into completely digital electrical signals and then counted without information loss. This adds a wealth of completely new clinically relevant information and improves image sharpness and contrast.

"About 15 years ago, work on photon counting and its clinical vision started at Siemens Healthineers. We always believed in the tremendous clinical value and relentlessly worked on it together with our partners. We are excited that we have received FDA 510(k) clearance," says André Hartung, Siemens' head of diagnostic imaging.

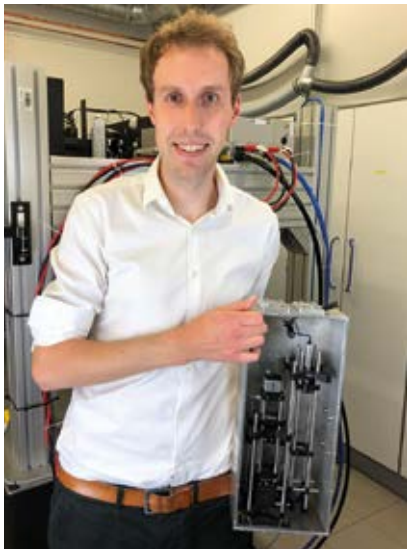
www.siemens-healthineers.com

Prototype in-line monitoring system for laser surface structuring

Development by researchers of TU Dresden within EU-funded LAMpAS project

The system allows monitoring of the process stability involved in laser structuring for the design of a new range of functionalized surfaces such as easy to clean finishes for ovens, fridges, and other home appliances.

The significance of this new prototype lies in the fact that, until now, a main difficulty in microstructuring using the direct laser interference patterning (DLIP) method has been detecting deviations in the obtained topography of the surfaces. However, with LAMpAS' prototype in-line monitoring system, a solution is at hand. It works by examining the light that is reflected from the laser-treated area using Fourier analysis. This is performed by using a low-power laser diode to illuminate the processed surface and a camera to collect the pattern reflected from the surface. The recorded image is then analyzed by an algorithm that is able to reveal changes in the shape and brightness of the reflected pattern. The upshot is that subtle deviations in the produced topography during the fabrication process can be detected and crucial information about the manufacturing process can be provided to the user.



TU Dresden researcher Nikolai Schröder with the prototype of the in-line monitoring system (Source: TU Dresden / EPIC)

The prototype consists of custom designed hardware with easy-to-use software. During the product development, special attention was given to achieving a compact and robust device. In the next steps, the researchers of the Technische Universität Dresden will focus on the final implementation and validation in real industrial manufacturing platforms.

LAMpAS was set up in 2019 with a grant of 5.1 million euros under the EU's Horizon 2020 program. The aim of this project is to develop the potential of laser structuring and to bring the technology to industrial levels at affordable costs. It aims to design newly functionalized surfaces by enhancing the efficiency, flexibility and productivity of processes based on the development of a high power, ultrashort-pulsed laser system together with advanced optical concepts for high-throughput materials processing.

Further reading: *L. Cangueiro, D. Bruneel (both: Lasea), T. Kiedrowski (Bosch), N. Schroeder, A. F. Lasagni (both: Technical University of Dresden), J. A. Ramos-de-Campos (Lasea):* Heat accumulation in metals under femtosecond irradiation: simulation and experimentation – Research on predicting the quality of laser processing of metals using femtosecond lasers for industrial purposes, PhotonicsViews **18**(5), 2021, pp. 30–33; DOI: 10.1002/phvs.202100056

www.tu-dresden.de
www.epic-assoc.com

Optica announces new vice president and directors-at-large

Gerd Leuchs, Judith Dawes, and Min Qiu join the board

The membership of Optica has elected Prof Gerd Leuchs, director emeritus at the Max Planck Institute for the Science of Light, Germany, as the society's 2022 vice president. Prof Judith Dawes, Macquarie University, Australia, was voted in as a director-at-large. The board of directors appointed Prof Min Qiu of Westlake University, China, as a director-at-large.

(l. t. r.) Gerd Leuchs, Judith Dawes, Min Qiu (Source: Optica)

Leuchs has been leading research groups since 1985, including a period from 1990 to 1994 when he worked in industry in Switzerland. He then moved on to the University of Erlangen-Nürnberg. Following a 5-year block grant by the Max-Planck Society, the new Max Planck Institute for the Science of Light was established in 2009. Leuchs served as a director until 2019, when he received emeritus status and continued leading a smaller-scale research group. He also works part time at the University of Erlangen-Nürnberg and is currently affiliated with the Institute of Applied Physics of the Russian Academy of Sciences in Nizhny-Novgorod. In addition, he has close ties to the University of Ottawa as professor adjunct.

"Gerd has been an active member of our organization throughout his professional life," said Optica CEO Elizabeth Rogan. "His groundbreaking work in laser spectroscopy and quantum communication and his extensive knowledge of our organization will be great assets." His four-year commitment to Optica's board of directors consists of serving one year as vice president in 2022, followed by one year as president-elect in 2023, president in 2024 and past president in 2025.

Judith Dawes is a professor of physics and director of Macquarie University's MQ Photonics Research Centre, Sydney, Australia, and is a member of the academic senate of the university. After holding postdoctoral positions at the University of Toronto, Canada, and Macquarie University, she was appointed to a faculty position at Macquarie where she served as head of the department of physics and astronomy from 2013 to 2015. An Optica fellow since 2019, Dawes' current research focuses on the collective interactions of light at the nanoscale, applying nanophotonics to imaging and sensing.

Min Qiu has been a chair professor of photonics and vice president for research at Westlake University, China, since April 2018. He received a PhD in physics from Zhejiang University, China, in 1999. Qiu received his second PhD degree in electromagnetics and became an assistant professor at the Royal Institute of Technology (KTH), Stockholm, Sweden, in 2001. He became a full professor at KTH in 2009 before moving to Zhejiang University in 2010, where he was the director of State Key Laboratory of Modern Optical Instrumentation.

www.optica.org

Laserlab-Europe elects Jens Biegert as new Director

New board members appointed by general assembly

The general assembly of Laserlab-Europe AISBL, the international not-for-profit association representing 45 leading laser research infrastructures in 22 European countries, elected Jens Biegert as new executive director and has appointed new management board members.

Biegert, ICREA professor at the Institut de Ciencies Fotoniques ICFO in Barcelona, and current chair of the association's general assembly, is succeeding Claes-Göran Wahlström from the Lund Laser Center in Sweden who served as executive director since the creation of Laserlab-Europe AISBL in 2018 and who will continue as a member of the management board.

The outgoing executive director, Claes-Göran Wahlström, remarked: "As Europe is strengthening its efforts in research and development to respond to urgent societal challenges, we need to make sure that the potential of demand and curiosity-driven laser research is unlocked and developed further."

The General Assembly of Laserlab-Europe AISBL also renewed the management board members and user representatives, with the election of Colin Danson, Cristina Hernandez-Gomez, Sylvie Jacquemot, Britta Redlich, Marc Vrakking, Claes-Göran Wahlström, and user representative Rosa Weigand onto the management board. Helder Crespo, Susan Quinn, and Rosa Weigand take office as user representatives.

The members of the general assembly congratulated Biegert and the members of the management board on their election and thanked Wahlström for his achievements and commitment in leading the Laserlab-Europe consortium. The new executive director is elected for five years and the management board for three years as of 2 November 2021.

ICREA Prof Dr Jens Biegert (Source: ICFO)

www.laserlab-europe.eu

PhotonHub Europe boosts innovations with photonics technologies

Mission to integrate best-in-class facilities, expertise and experience of 53 top competence centers across Europe under one roof

1st Pan-European Event on Regional Collaboration in Photonics, Paris, November 18 & 19, 2021. The event took place in accordance with the current Covid-19 hygiene conditions. (Source: Photonics France)

PhotonHub Europe is a new pan-European photonics digital innovation hub with the overall strategic mission of integrating all of the best-in-class photonics technologies, facilities, expertise and experience of 53 top competence centers across Europe under one roof as a full-service one-stop-shop solution. PhotonHub Europe will help European SMEs and mid-caps to boost their competitiveness and foster new business and business models through the faster and smarter deployment of photonics-based technologies.

The project partners are addressing photonics and non-photonics companies anywhere in Europe that want to innovate with photonics. The project may offer subsidized (up to 100 %) support in the field of photonic innovation as well as for low technology readiness level (TRL), as well as for higher TRL levels such as prototypes, alpha / beta products, or manufacturing process planning and optimization. PhotonHub Europe has therefore been awarded 19 million euros of investment from the EU's Horizon 2020 program.

The key aspects/services in the PhotonHub Europe concept are:

- innovation support 'test-before-invest'
- education and training using lecture-based tutorials and hands-on, lab-based training
- business support services and support to find investment
- innovation ecosystem and networking

The German partners of PhotonHub Europe are OpTecBB and the Fraunhofer HHI in Berlin, OptoNet in Thuringia, Fraunhofer FEP in Dresden, Fraunhofer ILT in Aachen, the Karlsruhe Institute for Technology (KIT), the Laser Zentrum Hannover (LZH), and the Leibniz Institute for Photonics Technologies (IPHT) in Jena.

A long-term cooperation between PhotonHub Europe and Photonics Germany, the alliance of OptecNet Germany and Spectaris, is being planned to strengthen the photonics industry in Germany.

In November 2021, more than forty representatives of the national platforms and regional clusters met in Paris to provide an overview of the funding opportunities for photonics in Europe, such as:

- a market data and industry report on European photonics
- the Photonics Partnership in Horizon Europe
- InterReg Europe
- the Future of the S3 Platform
- the PhotonHub project

Prof Dr Hugo Thienpont from the Vrije Universiteit Brussel, the PhotonHub Europe coordinator, also presented PhotonHub Europe and its services during the Photonics Days Berlin Brandenburg 2021 in Berlin in October, and within the framework of the OptecNet Germany annual meeting 2021 in Hannover in November.

Interested parties are invited to get in direct contact with the central office of PhotonHub Europe based in Brussels or with the local photonics hubs all across Europe. Details are available at:

www.photonhub.eu

German Evening at SPIE Photonics West in San Francisco

The German Evening in San Francisco is well established and highly appreciated by the SPIE Photonics West exhibitors. In 2022, the event will be organized for the first time by Photonics Germany, the alliance of Spectaris and OptecNet Germany. The German Evening will take place at the Leica Store in San Francisco on January 26, from 7 to 10 pm.

We look forward to an exciting event with numerous networking opportunities on photonics and quantum technologies. Participation is by invitation of Photonics Germany. More information at:

www.photonics-germany.de

Source: Photonics Germany

Photonics Germany elaborates a position paper for a new funding program

Photonics acts as an enabling technology and solution provider for numerous industries such as the automotive sector, medicine and biotechnology or industrial manufacturing. Whether digitalization, electrification or decarbonization – the photonics industry significantly contributes to overcoming major challenges of our time.

Photonics Germany, the alliance of OptecNet Germany and Spectaris, strengthens the German photonics industry at a national and European level. A prime activity is the initiation and further development of research funding, thereby fostering technological innovation as well as the competitiveness of companies and research institutions.

Photonics Germany is currently developing a position paper with subject proposals for a new photonics funding program. The overall goal is to strengthen the competitiveness of the photonics industry as well as to emphasize the importance of longterm photonics research funding. For this purpose, Photonics Germany directly involves its members by investigating relevant topics and framework conditions.

The potential of the photonics industry was recently illustrated within the keynote of Dr Bernhard Ohnesorge, managing director of Carl Zeiss Jena and chairman of photonics at Spectaris, during the OptecNet Germany annual meeting 2021. He emphasized both the ongoing innovative strength of photonics as a key enabling technology as well as the importance of targeted research funding in this field.

https://photonics-germany.de

EMVA Young Professional Award 2022 – call for application

Prestigious industry award with prize money, presentation at EMVA Business Conference

The EMVA Young Professional Award is an annual award endowed with 1,500 euros to honor the outstanding and innovative work of a student or a young professional in the field of machine vision or image processing.

Applicants for the EMVA Young Professional Award are hereby invited to submit their work. The criteria of the works to be presented are:

- Outstanding or innovative work in the field of vision technology. Industrial relevance and collaboration with a company during the work is required. The targeted industry is free of choice.
- The work (master or PhD thesis or equivalent level research) must have been undertaken within the last 18 months at, or in collaboration with, a European institution. Meanwhile the student may have entered the professional field.

Applicants may submit the following materials to the EMVA President, Dr Chris Yates, at ypa@emva.org latest until March 31st, 2022:

- a two-page abstract summarizing the innovation and the intended commercial benefit
- a one-page CV
- a copy of the master thesis or PhD thesis. If not yet finished or under publication restrictions, please provide at least one accepted paper

With the award, the EMVA would like to specifically encourage students and young scientists to focus on challenges in the field of machine vision and to apply latest research results and findings in computer vision to the practical needs of our industry.

The winner of the award will be announced at the EMVA Business Conference 2022 and will have the opportunity to present the awarded work to the machine vision industry leaders from Europe and abroad. The presentation may then be published by the international machine vision press. In addition to the honor of the EMVA Young Professional Award and the publicity for the research work is a free conference pass for the EMVA Business Conference as well as the coverage of all travel cost to Brussels and a free pass for the 2022 European Machine Vision Forum in Ireland.

www.emva.org/news/emva-young-professional-award-2022-call-for- application

20th EMVA Business Conference 2022 takes place in Brussels

Location change due to low vaccination rate in former host country – early-bird registration is open

The European Machine Vision Association (EMVA) relocated the next EMVA Business Conference 2022 to take place from 12 – 14 May 2022 in Brussels, Belgium. Considering the low vaccination rates in Bulgaria, the originally planned destination Sofia had to be changed.

Brussels as a center of European politics provides the appropriate infrastructure to plan and execute an international conference in challenging times where at the same time everyone longs for personal encounters.

The conference program will address up-to-date technical topics as well as relevant management, marketing and/or leadership issues. Use cases and a panel discussion will give further interesting insights. Last but surely not least, the conference will provide plenty of excellent networking opportunities during the evening events or by means of pre-scheduled face-to-face meetings in the conference break-out sessions. Registration for this pivotal conference event in the machine vision industry taking place in Belgium next year is now open at reduced early-bird conference fees. More information is available at

www.business-conference-emva.org

What to expect in 2022?

EPIC starts the new year with 750 members and a full calendar of events

The world's largest photonics industry association is growing steadily and currently serves 750 member companies with full member services. The core team is also growing as three new employees were hired before the end of 2021. Panagiotis Vergyris, based in Rome (Italy), has joined the technical team as photonic technologies program manager, with expertise in quantum technologies. The marketing and events team will now be supported by two new marketing managers: Anna Trachtova, based in Prague (Czech Republic) and Elisenda Lara, based in Barcelona (Spain).

In 2021, EPIC organized 70 virtual events. In addition to online technology meetings, other formats such as virtual company tours, product launches, and webinars were held regularly. The association also published four market reports and started travelling again. In the last quarter of 2021, the team participated in several international photonics trade shows and attended major exhibitions such as ECOC, W3+, Vision, Medica / Compamed, and others.

As the new year begins, EPIC is full of ideas and big plans. Two major physical events are planned for the first half of this year. EPIC's World Photonics Technology Summit, specifically for CTOs of member companies, will take place on 24 January 2022 in San Francisco (USA). And the Annual General Meeting, aimed at CEOs and other C-level positions, will be held on 7 / 8 April 2022 in Vilnius (Lithuania). Various supporting events will be held in conjunction with these conferences.

The most popular virtual format, EPIC Online Technology Meetings, will be held on Mondays on a weekly basis, starting on 17 January, where the focus will be on novel thin materials. EPIC has already announced 18 new topics for the period January to June 2022. Combining the existing online activities with successful face-to-face meetings will be the main goal of the association for the next year.

www.epic-assoc.com

Upcoming EPIC events:

- 23 January 2022
  Welcoming Reception of EPIC World Photonics Technology Summit, San Francisco, USA
- 24 January 2022
  EPIC World Photonics Technology Summit, San Francisco, USA
- 25 January 2022
  Pilot Lines & Photonics Innovation Hubs Breakfast, San Francisco, USA
- 25 – 27 January 2022
  EPIC Members Lunch, San Francisco, USA
- 26 January 2022
  EPIC Executive 5 Miles Run, San Francisco, USA
- 31 January 2022
  EPIC Online Technology Meeting on UV Disinfection
- 7 February 2022
  EPIC Online Technology Meeting on Quantum Computing Platforms
- 14 February 2022
  EPIC Online Technology Meeting on Lighting for Automotive
- 21 February 2022
  EPIC Online Technology Meeting on Mid-Infrared Alliance Present and Future
- 7 March 2022
  EPIC Online Technology Meeting on Additive Manufacturing of Metal and its Applications
- 14 March 2022
  EPIC Online Technology Meeting on Agriphotonics
- 21 March 2022
  EPIC Online Technology Meeting on Single Photon Sources and Detectors
- 28 March 2022
  EPIC Online Technology Meeting on Laser Range Finders and Sports Optics
- 4 April 2022
  EPIC Online Technology Meeting on Hybrid Photonic Integrated Circuits
- 7 – 8 April 2022
  EPIC Annual General Meeting 2022, Vilnius, Lithuania

www.epic-assoc.com/epic-events

EPIC
European Photonics Industry Consortium

EPIC PROMOTES THE DEVELOPMENT AND COMPETITIVENESS OF THE EUROPEAN PHOTONICS INDUSTRY AND ITS MEMBERS

www.epic-assoc.com

Photonics lights up financial markets with first thematic index

EPIC has collaborated with Solactive in developing the world's first investable index that tracks the photonics industry on a global scale

Antonio Raspa

Source this: Solactive; all other: EPIC

With a higher start-up success rate than for most industries, and growing far more rapidly than other technologies, many sensors, systems, and components are emerging that are faster and more miniaturized. A new industry has emerged that rivals the exponential growth of the semiconductor industry.

Between 2014 and 2019, the global non-photonic microelectronics market grew from 336 to 412 billion euros. However, by comparison, the global photonics industry has grown geometrically over the past fifteen years. The global photonics market was worth € 733 B in 2019 and is expected to reach approximately € 1,000 B by 2025. This is a fast-growing industry compared to other high-tech industries.

You do not have to go look up the Wikipedia definition of photonics to understand the impact of scientific studies and technologies related to the generation, manipulation and revelation of light in every economic sector. Photonics permeates the daily life of all of us, from smartphones, televisions, laser printers, LED lighting to more advanced applications such as machining, medical diagnostics and security systems.

▲**Fig. 1** Solactive EPIC Core Photonics Index, retrospectively.

And the number of companies using and depending on photonics to characterize elements or key functionality of their products and services is continuously increasing. Photonics has all the characteristics to be the disruptive technology of the near future but, pre-

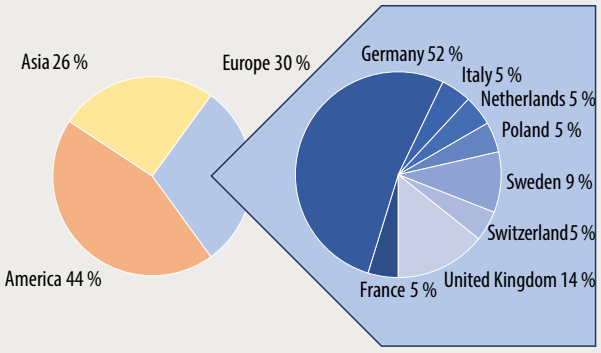


Fig. 2 Geographical distribution of index constituents by number of constituents

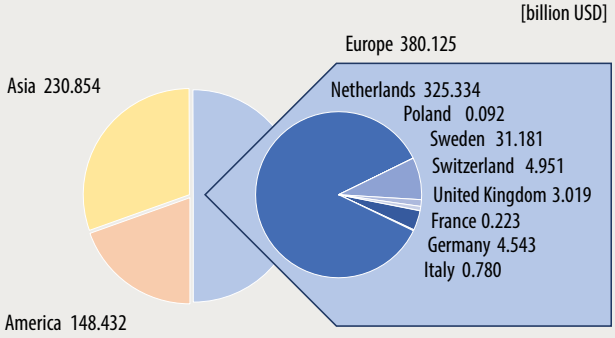


Fig. 3 Geographical distribution of index constituents by free-float market capitalization

cisely because of its high transversality, it is (still) unknown to most investors.

Always looking for ways to support the photonics community and offer new opportunities for its members, EPIC – the European Photonics Industry Consortium – recently announced the launch of the Solactive EPIC Core Photonics Index, the first thematic index based on photonics companies present on the world stock markets. This index is a tool to assess the ROI of the photonics industry, a sector that historically shows an average annual growth rate (CAGR) of 25.9 % over the period 2015 – 2021 (see Fig. 1).

"To invest in photonics, you need to know the industry in detail and carefully select individual companies. With this index, which is based on about seventy companies, you have both a clearer view of industry trends and a concrete tool to reduce volatility and consequently the risk in investments," says Carlos Lee, managing director of EPIC. "We will build on this index to generate positive effects for the industry and in particular for EPIC members. We imagine that soon every person who wants to ride the wave of photonics will be able to invest in a new financial product based on this index."

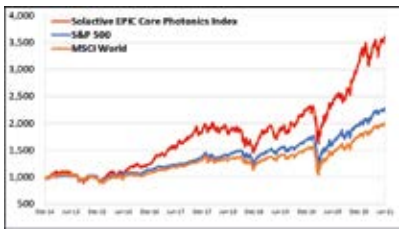
The index was released on May 28, 2021, and since its inception there have been several positive feedbacks, such as that from Danish company Shute Sensing Solutions, which stated their intention to include the index performance graph in their presentations to investors. On the other side of the Atlantic, US-based Lightwave Logic (Stock: LWLG) has been actively promoting its inclusion in the index and the news has been picked up by various sites such as Yahoo, the Financial Times and others.

EPIC has always been committed to supporting the creation and growth of photonics companies. With this new photonics index, EPIC is informing financial investors and highlighting the potential of markets and applications and expects that the publication of the index will very soon result in greater recognition and credibility of the photonics industry. In addition, the EPIC members will have greater access to the financial investment community, will be better informed about various options for raising funds, and will benefit from increased business-related activities and corporate growth.

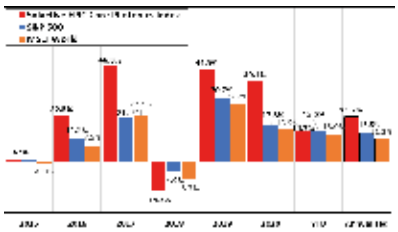
The Solactive EPIC Core Photonics Index is the result of a long-standing cooperation between EPIC and Solactive, a German Frankfurt-based company that has been developing bespoke, multi-asset class indices for ETFs and other indexed investment products with leading global investment banks and asset managers since 2007. EPIC in particular, based on its detailed knowledge of the industry, developed the index methodology, i.e. the criteria for the inclusion of companies in the index from a universe of approximately 350 companies engaged at various levels in photonics. EPIC is also responsible for the ongoing monitoring of the photonics industry and a periodic review of the data underlying the index composition. For details, please refer to the official documents available on the Solactive Web site [1].

The numbers for photonics are already impressive today and will be even more so in the coming years and decades. Carlos Lee explains, "Photonics is likely to be the next technology wave: currently, the photonics market is valued at nearly 800 billion dollars and is expected to reach 1.2 trillion by 2026, based on eight percent growth per year." Also, based on a direct comparison with two other much better known global indices such as the S&P 500 and MSCI World, it is possible to say that photonics will increasingly catalyze the attention of financial markets (Fig. 4). In addition to the clearly positive performance of the Solactive EPIC Core

Index Returns*



Annual Returns*



Performance Comparisons*

Dec. 31 2014 - Jun. 30 2021	Solactive EPIC Core Photonics Index	S&P 500	MSCI World
Cumulative Return	258.0%	128.3%	99.2%
CAGR	21.7%	13.5%	11.2%
Volatility Overall	17.0%	18.0%	15.2%
Volatility LTM	16.9%	16.4%	13.9%
Correlation		72.20%	81.28%

Volatility*

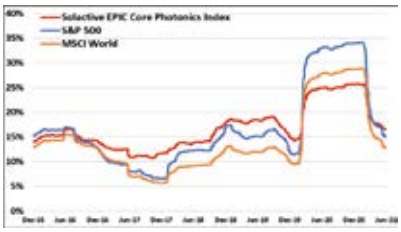


Fig. 4 Comparisons: Solactive EPIC Core Photonics Index vs. S&P 500 Index and MSCI World Index

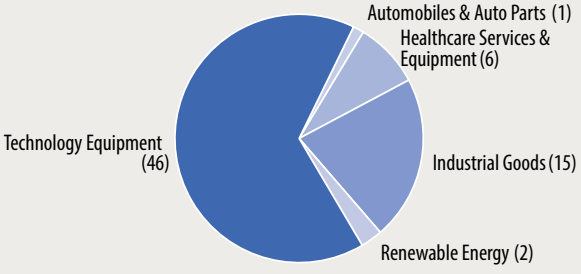


Fig. 5 Solactive EPIC Core Photonics Index breakdown according to the TRBC industries – number of companies

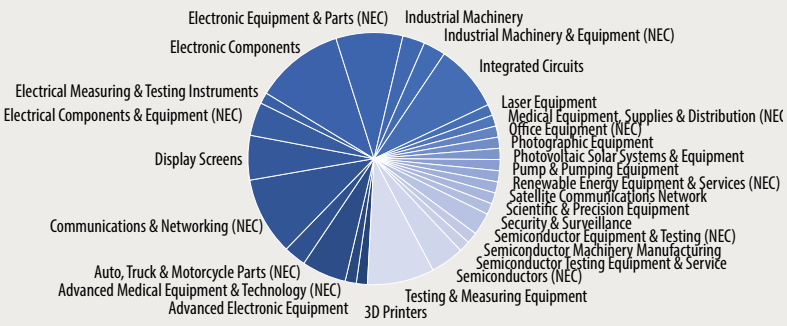


Fig. 6 Solactive EPIC Core Photonics Index breakdown according to the TRBC activities – number of companies

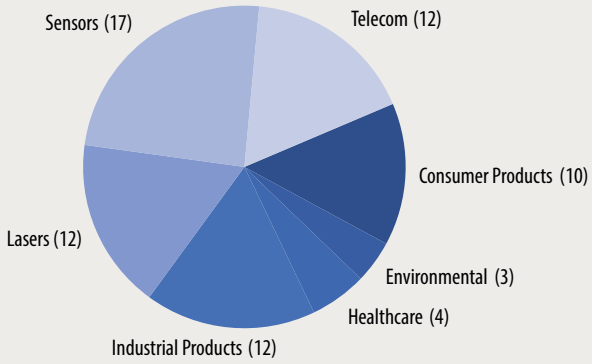


Fig. 7 Index breakdown according to the GPC categories – number of companies

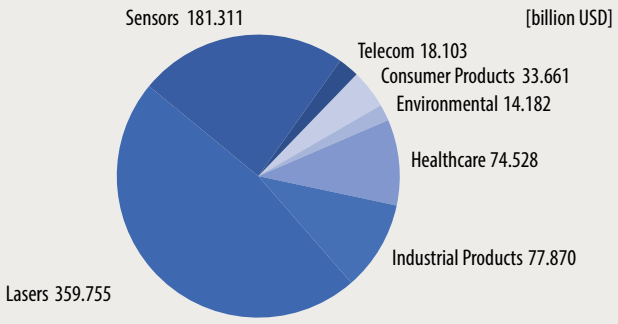


Fig. 8 Index breakdown according to the GPC categories – free-float market capitalization

GPC categories	GPC applications and markets
industrial products	OEM raw materials/components for industrial applications
consumer products	OEM components for consumer products
lasers	laser sources & laser material processing equipment
environmental	solar energy & environmental improvement
telecom	telecommunications, satellite & internet equipment
healthcare	photonics for healthcare and well-being
sensors	photonics sensors and monitoring equipment
defense	defense & security

Table 1 Global Photonics Classification adopted by EPIC

Photonics Index shown in Fig. 1, there are several other relevant factors, starting with the carbon footprint of the companies in the Index that is on average ninety percent lower than market benchmarks such as the S&P 500 and MSCI World: photonics is definitely a major enabler of a cleaner environment.

Other interesting aspects are, firstly, the geographical distribution (Fig. 2), which does not show any imbalance or predominant areas when the number of companies is taken into account and, secondly, the total free-float market capitalization by country (Fig. 3).

Going further into the composition of the index using the Thomson Reuters Business Classification (TRBC) that is typically used in the financial world to address industry sectors, it is evident that the components of the photonics index are distributed at first level into several main categories and really spread into many specific sectors and applications (see Figs. 5, 6). These graphs confirm how photonics is definitely transversal to multiple industries and how important its strategic role is. Nevertheless, it is very attractive to the financial world that there is no concentration in a specific manufacturing activity, with the resulting 'balancing' of risk. On the other hand, we have learned that, because of its large cross-cutting role, it is very difficult to explain to financial operators that photonics is really everywhere and that it is a key technology that enables all industries to become more effective, more productive, and far more energy efficient.

So a new classification has been developed that is more adherent to the real structure of the photonics industry and, at the same time, can convey in a simple and clear way how important its role is for the various current market sectors, and even more so for the future ones. The Global Photonics Classification (GPC) is structured into eight categories (see Table 1) that address the huge constellation of photonic applications that satisfy the basic needs of everyday life but are often not immediately apparent.

The breakdown of the components of the index according to the GPC categories is shown according to the number of companies (Fig. 7) and free-float market capitalization (Fig. 8). It should be noted that the index methodology excludes companies with turnover above fifty percent in the military sector. By adopting the GPC classification instead of the TRBC to analyze the Solactive EPIC Core Photonics Index, EPIC definitely achieves greater clarity on the enabling role of photonics and this will enable better communication with financial stakeholders.

EPIC expects that the industry consolidation will drive investment returns in the photonics sector over the next ten to twenty years, and while individual company returns are potentially very high, it is difficult for investors to

Organization

EPIC – European Photonics Industry Consortium

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distinguish between winners and losers over time. This is why a thematic index approach might make more sense.

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For more information on the Solactive EPIC Core Photonics Index, visit www.photonics-index.org.

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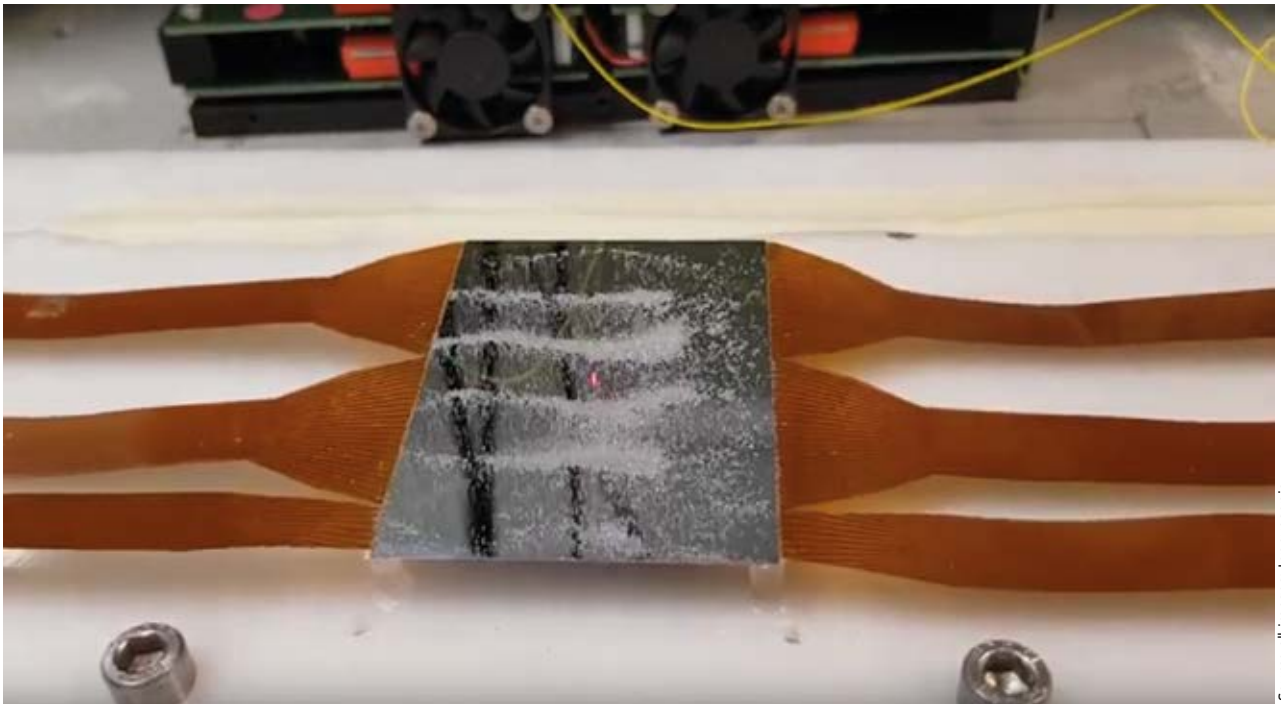
[1] https://solactive.com/downloads/Solactive_EPIC_Core_Photonics_Index.pdf

The long and winding road to market

An EPIC interview with Boris Kobrin, CEO of Innovasonic

Jose Pozo



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How long it takes before patience pay off can never be known in advance. Sometimes the development of a new product or process is surprisingly quick, even for those who invented it. On other occasions, bringing a good idea to fruition can take a frustratingly long time. In this article, EPIC's CTO Jose Pozo follows the career of and talks to Boris Kobrin, CEO of Innovasonic, a developer of advanced smart glass technologies.

In 1980, after graduating with an MSc in physics from Tbilisi State University in Georgia, Boris started a PhD in solid-state physics at the Russian Academy of Sciences in Moscow, and completed it successfully in 1985. He emigrated to Israel In 1991 following the break-up of the Soviet Union and worked in a company called HoloOr Ltd., pioneering diffractive optics fabrication technology for laser material processing.

Five years later he moved to Quebec in Canada to work for QPS/Bragg Photonics as R&D manager, responsible for setting up a fiber Bragg grating manufacturing facility. Then he continued his micro-optics technology development at Rochester Photonics Corp. in the US.

In 1998 he was invited to join Plasma-Therm's application lab in Florida as project leader in charge of their data storage manufacturing technology and the development of semiconductor etching and deposition equipment processes. Then, following the acquisition of the company by Unaxis/Oerlikon, in 2000 Boris moved to California to work for the UC Berkeley's spin-off Onix Microsystems, where he helped to develop optical switches based on Si bulk micromachining MEMS technology.

Start-ups

Things went well until the telecom crash in 2002 closed down many start-ups, including Onix. After a few months of soul searching, he was invited to set up Applied Microstructures by a good friend and ex-executive from Applied Materials. The aim was to develop atomic layer (ALD) and chemical vapor deposition (CVD) equipment for the deposition of organic and metal-organic ultrathin films from a vapor phase. The company sold hundreds of tools worldwide and in 2007 was bought by SPTS Technology.

The following year, Boris has set up his second company, Rolith Inc., to commercialize proprietary technology relating to large surface area, high-throughput and low-cost lithography. The company did well, developing the technology for specific applications such as antireflective coatings

as well as transparent metal mesh conductor applications such as touch sensors, transparent heaters, and antennas. This technology was awarded "The Best Manufacturing Technology" by Printed Electronics Industry in 2013. Rolith was eventually sold in 2016 to the Canadian company Metamaterial Technologies Inc. (MTI) and for two years Boris served as a Metamaterial board member and company CTO.

Boris Kobrin, CEO of Innovasonic

InnovaSonic

InnovaSonic Inc. was Boris' third company, and the second that he co-founded with Julian Zegelman and Joseph Geddes – both from Rolith – in 2016 to commercialize innovative, advanced, smart glass self-cleaning, disinfection and haptics application technologies for touch screens, automotive sensors (cameras, lidars), and other markets.

Ultrasonic self-cleaning: Innovasonic's technology for self-cleaning is based on a proprietary transparent ultrasonic transducer array concept (PiezoWipe), which creates ultrasonic vibrations that are able to remove various types of contamination, including environmental (dust, dirt, mud, bugs) and weather contaminants (raindrops, fog, ice).

The system can be used in combination with passive hydrophobic coatings and the process is performed on-demand or automatically, using sensors to detect the type and location of contamination. The technology does not require any human attention, labor, materials or chemicals and the removal of contamination and icing is fast while energy consumption is low as there is no heating involved. Unlike other self-cleaning systems that attach discrete transducers on the periphery of the glass, Innovasonic's solution allows the distribution of piezoelectric transducers across an entire transparent product surface, such as camera lenses and lidar sensors, and can potentially provide local cleaning, saving significant amount of energy.

As Boris explains, the idea for the technology came from the use of ultrasonic vibration to remove dust from DSLR camera sensors by vibrating the frame where the sensor is positioned. Additionally, F 16 fighters used ultrasonic vibration to remove dust from the cockpit window, although the transducers were bulky and required a lot of energy as they had to vibrate a heavy canopy.

In principle, this technology could be applied to any object and, having previously worked on transparent arrays of materials that could be blended with optical elements without losing transmission, Boris began to experiment with piezoelectric materials. The basic idea was to deposit a thin piezoelectric film, then pattern it with mesh geometry to keep transmission loss to a minimum.

The next stage was to produce a prototype, which they did in collaboration with the CEA-LETI and CEA-LIST institutes based in France, and also to apply for patents to protect the idea. Although the prototypes have demonstrated some good results, there is room to improve and enhance performance before the technology can be demonstrated for real products.

As regards future customers, the largest potential sector is the automotive industry, which has already expressed interest in the technology for self-cleaning cameras, mirrors and lidars that are mostly located outside of the vehicle. A key selling point for automotive is that the technology can be scaled at low cost. As Boris explains, the technology is essentially based on semiconductor processing, which is known for economy of scale. Although piezoelectric material is quite expensive, the thin patterned film implementation keeps the cost down, such that the extra cost per square meter works out at between ten and twenty dollars, which for a square inch camera lens is minimal.

Next-generation touch screen haptics: Haptics technology, from the Greek word haptikos meaning "tactile, pertaining to the sense of touch", stimulates the senses of touch and motion and provides sensations that would be felt by a user interacting directly with physical objects. Due to enhanced user experience and safety aspects, every significant producer of electronic devices is now investing seriously in haptics, from consumer electronics to heavy industrial machinery.

Innovasonic's proprietary ultrasonic surface haptics technology (PiezoTouch) is based on thin film piezoelectric transducers fabricated across an entire touch screen window. This concept allows the seamless integration of haptics devices with touch sensors to simplify manufacturing and lower the cost.

Applications for haptic feedback technology are wide ranging, including VR/AR, gaming, and medical simulation training in procedures such as laparoscopy and dentistry.

By generating specific frequency responses, the technology enables the

Background image source: Getty Images / iStockphoto

Touch screen disinfection scheme

PiezoWipe™ prototypes

user to feel different textures, like velvet, wood and stainless steel, etc.

The most attractive application though is in the automotive market where these next-generation haptics would allow the tactile operation of touch screen infotainment systems by enabling virtual control elements (buttons, sliders). This technology removes the safety issues of operating a touch screen in a moving vehicle – allowing operation without the need for the driver to take their eyes off the road to look at the screen.

Touch screen disinfection technology: Another application for the technology is to disinfect touch screens used by the general public, e.g. ATMs, to reduce the risk of bacteria and virus transmission, including Corona.

Research started in 2020 with the support of a grant from the US National Science Foundation with the initial idea that disinfection could be achieved with ultrasonic transducers attached to glass. However, they found that the main effect was thermal rather than ultrasonic; that is, embedded transparent conductors in glass could produce high enough temperatures (60 – 70 °C) to kill bacteria and other pathogens.

As a result, Innovasonic pivoted their technology to thermal disinfection and are currently working on two configurations. The first is hot surface disinfection (HSD), where the touch screen is heated to 70 °C during operation of the device in order to continuously disinfect the glass surface. The second option is thermal pulse disinfection (TPD), whereby the touch screen operation is interrupted for <1 min to perform the disinfection cycle i.e., the temperature of the glass is raised to >120 °C and then quickly cooled down.

The advantage of this approach is that the disinfection method does not require UV or any chemicals or consumables and it is automatic, fast and safe for customers. Most importantly, it enables disinfection after each customer, which is essential to cut the spread of contamination. Furthermore, the cost is minimal because the transparent conductor films are commodities and integration with existing touch screen devices is quite straightforward. The proprietary concept of local disinfection, just for the areas potentially contaminated by a person's fingerprints, could also cut energy consumption and accelerate the disinfection process significantly. This option is realized using existing touch sensors that detect where the screen has been touched and only this part is heated, which avoids heating the entire screen.

If you started again, what would you do differently?

"Back in the 80s when I finished my PhD, I wouldn't have been able to do anything differently because the options available in the Soviet Union were extremely limited. But if I started again in the West, I would definitely create my own companies much earlier.

I set up my first start-up in my forties, which was very late compared to nowadays when students who haven't even finished their masters' are spinning off companies from places like Stanford and Berkeley. But I'm not sure if this is a good idea because, before setting up a company, it is important to get sufficient knowledge, education and experience and not be too narrowly specialized."

What advice do you have for the next generation of entrepreneurs?

"First, start-ups need to be flexible. Of course, you need to push your idea to fruition, but then again, if the response from technology or the market is not adequate, it may be necessary to pivot, use a different technology to solve the same problem or use the same technology to solve a different problem for a different market. In most cases it is possible.

Second, you need to approach life with your eyes open and not be blinded by the desire for a quick turnaround – you are not a venture capitalist after all – because it is very easy to be blindsided by, for example, two or three years of good results or quick IPOs.

Third, and most important, for long term success you need to be patient. Everything takes two to three times longer than you can anticipate or feel reasonable …"

Author

Jose Pozo is director of technology and innovation at EPIC, and as such he represents more than seven hundred leading corporate members active in the field of photonics. His work consists of actively engaging with them and providing them with the tools to strengthen their position in the supply chain. He has twenty years' background in photonics technology, market knowledge, and a large network within the industrial and academic photonics landscape. Jose holds a PhD in electrical engineering from the University of Bristol, UK, and an MSc and a BEng in telecom engineering from Spain and Belgium.

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Comparing the sheet metal welding performance of different lasers

Performance tests of MOPA ns-pulsed fiber laser, qcw fiber laser and yttrium aluminum garnet laser

Lulu Song

Laser technology has developed progressively over the last sixty years. It is commonly used for traditional processing applications, for example for cutting, marking and welding, especially in industries such as aerospace that are exploiting the use of advanced materials.

Laser welding is used to join pieces of metal or thermoplastic. A high-density beam is focused onto the surface of the materials, causing them to melt and interfuse. The materials crystallize after cooling down and a tight join is formed. This technology has many advantages over conventional welding processes. First, laser beam irradiation causes the crystal grain to grow unidirectionally and exhibit a very fine dendrite structure, resulting in excellent mechanical properties and therefore exceptional anti-cracking and anti-porosity capabilities. Second, the small size of the laser beam affords much lower thermal stress and thermal effects, so the joining of refractory materials and dissimilar metals is increasingly feasible. Moreover, laser welding emits less harmful substances.

▲ JPT Opto-Electronics MOPA ns-pulsed fiber laser (Source all images: JPT)

item	ns-pulsed fiber laser	qcw fiber laser	YAG laser
average output power	120 W	500 W (cw); 150 W (pulsed)	350 W
central wavelength	1,064 nm	1,080 nm	1,064 nm
frequency range	1 – 1,000 kHz	0 – 1,000 Hz	– 150 Hz
max. pulse energy	1.5 mJ	15 J	80 J
pulse width	10, 20, 30, 60, 100, 200, 250, 350 ns	0.05 – 50 ms	0.3 – 20 ms
cooling method	air-cooled	water-cooled	water-cooled
consumption	<600 W	1.1 kW	12 kW

Table 1 Specifications for laser models used for welding evaluation

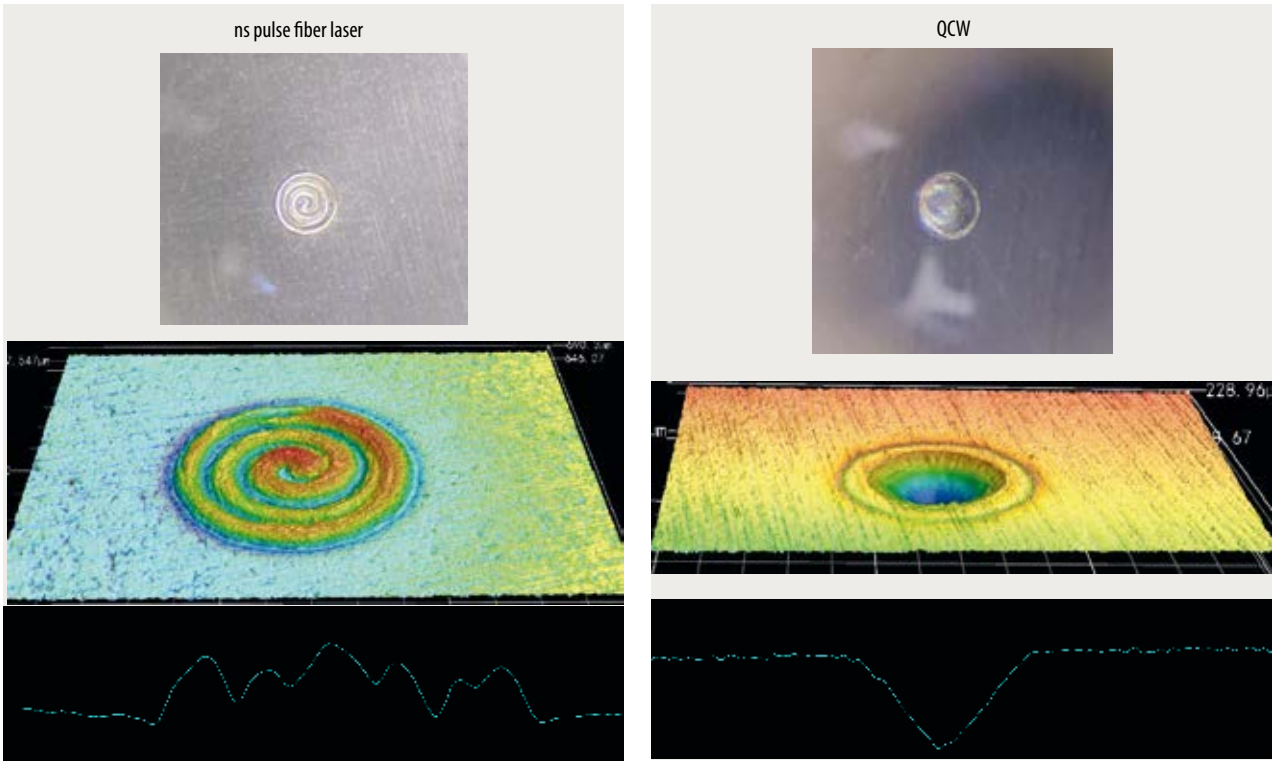

Fig. 1 3D profiles of the molten pools produced using the ns-pulsed fiber laser (left) and quasi-cw fiber laser on steel (right)

There are various types of laser for different applications on the market. For laser welding alone, there are many types of laser for different techniques. This article focuses on the welding performance of three types of laser, namely the master oscillator power amplifier (MOPA) nanosecond (ns) pulsed fiber laser, quasi-continuous wave (qcw) fiber laser and yttrium aluminum garnet (YAG) laser. The ns-pulsed fiber laser is based on the MOPA structure and features eight adjustable pulse widths. The parameters of these lasers are compared in Table 1.

Shenzhen JPT Opto-Electronics undertook two welding tests to assess the performance of the three lasers. The first test was carried out using the ns-pulsed fiber laser and qcw fiber laser on steel. The 3D profiles of the molten pools are shown to be different in Fig. 1, which is due to different welding principles. The welding spot of the ns pulsed fiber laser is spiral and therefore its molten pool is more uniform than that of the qcw fiber laser. Furthermore, the drawing force of the ns-pulsed fiber laser is more significant. However, the thermal effect of the qcw fiber laser is much smaller than that of the ns-pulsed fiber laser due to a short interaction time. The welding spot is generated by one emission and the molten pool is close to cone-shaped.

The second test was carried out using the ns-pulsed fiber laser, qcw fiber laser and YAG laser on thin dissimilar metals, namely aluminum-brass, brass-steel, brass-copper, copper-steel and titanium-steel. The parameters of the three lasers used on these materials are compared in Fig. 2a.

The focused beam diameter of the ns-pulsed fiber laser is smaller than those of the qcw fiber laser and YAG laser. The welding spots for the qcw fiber laser and YAG laser are generated using one emission, but the welding spot for the ns-pulsed fiber laser is spiral so that it is similar in size to the other two. The pulse energy is 1.5 mJ for the ns pulsed fiber laser, and it is 15 J for the qcw laser and YAG laser. Therefore, it takes the pulsed fiber longer to achieve the same sized welding spot. Observing the cross-section, the molten pool is serrated using the ns pulsed fiber laser, whereas it is made hollow using the qcw fiber laser and the YAG laser. Furthermore, the beam quality of the qcw fiber laser is far superior to that of the YAG laser, meaning the cross-section is close to cone-shaped.

Detailed metallographic examination results for the ns-pulsed fiber laser

Item	ns-pulsed fiber laser	qcw fiber laser	YAG laser
dissimilar thin metal	good	normal	normal
spot finishing	good	good	normal
thermal effect	normal	good	normal
welding surface	normal	good	good
power efficiency	good	good	normal

Table 2 Summary of the welding performance of different laser types

Company

Shenzhen JPT Opto-Electronics

Registered in 2006, JPT concentrates on the R&D, production, sales, and technology service of optical fiber devices, lasers and laser intelligent equipment.

Based on laser technology, JPT integrates leading technologies such as laser and optics, test and measurement, motion control and automation, and machine vision. The company highly values intellectual property and has applied for more than 600 patents.

JPT ranks: top 1 of MOPA pulsed fiber lasers globally, top 3 of fiber laser manufacturers in China.

www.jptoe.com

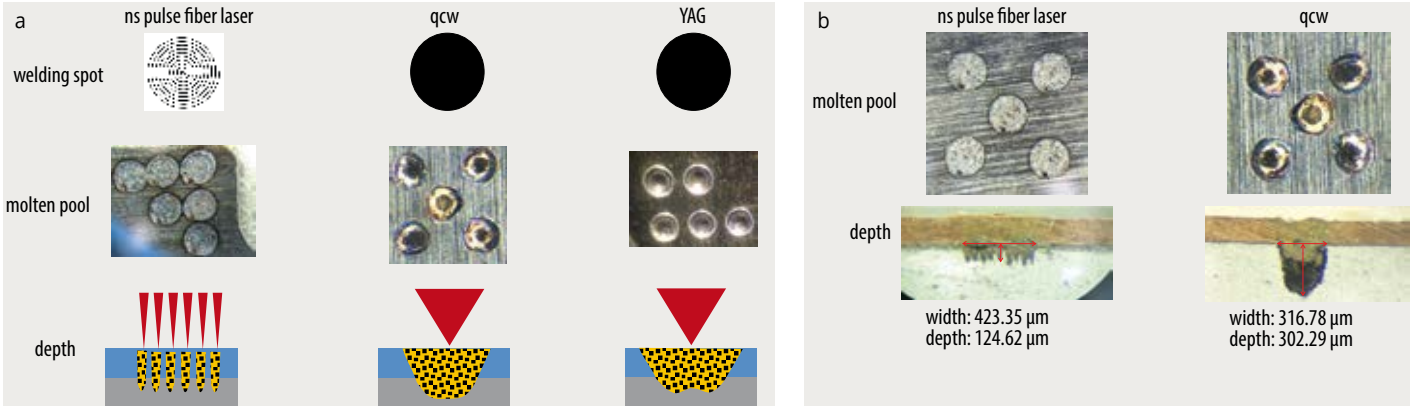

Fig. 2 Parameters of the ns-pulsed fiber laser, qcw fiber laser and YAG laser on dissimilar metals (a). Metallographic data for the ns-pulsed fiber laser and qcw fiber laser on copper-steel (b).

and qcw fiber laser on copper-steel are shown in Fig. 2b. The aspect ratio of the welding area used by the qcw fiber laser is close to 1 : 1, while the drawing force is more significant for the ns-pulsed fiber laser.

The welding performance results for the three lasers are summarized in Table 2. The welding performance is of course different for each type of laser. The ns-pulsed fiber laser is recommended for dissimilar metal welding, especially for thin materials. It achieves a delicate balance between melt and vaporization. The energy has to be sufficient to melt the material, but not so much as to vaporize it. Furthermore, the MOPA structure affords the benefit of flexible pulse control. The ns-pulsed fiber laser is widely used for the welding of 3C products because precise process parameters can be satisfied.

The beam quality of the qcw fiber laser is well-controlled and larger than that of the YAG laser, therefore delivering better spot finishing, thermal effect and welding surface.

It is important to choose the right laser for the application as this leads to a higher welding success rate. Shenzhen JPT Opto-Electronics has a specialized application lab, highly trained engineers and various equipment for different applications (cutting, marking, welding, etc.) to help customers evaluate laser processing characteristics.

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Lulu Song, sales engineer from Shenzhen JPT Opto-Electronics, is well experienced in laser technology, from laser principles to laser applications. After getting a master of science degree, she joined JPT and serves many well-known laser industry customers. As a bridge between laser source providers and laser manufacturers, Lulu's task is to offer quick and professional support.

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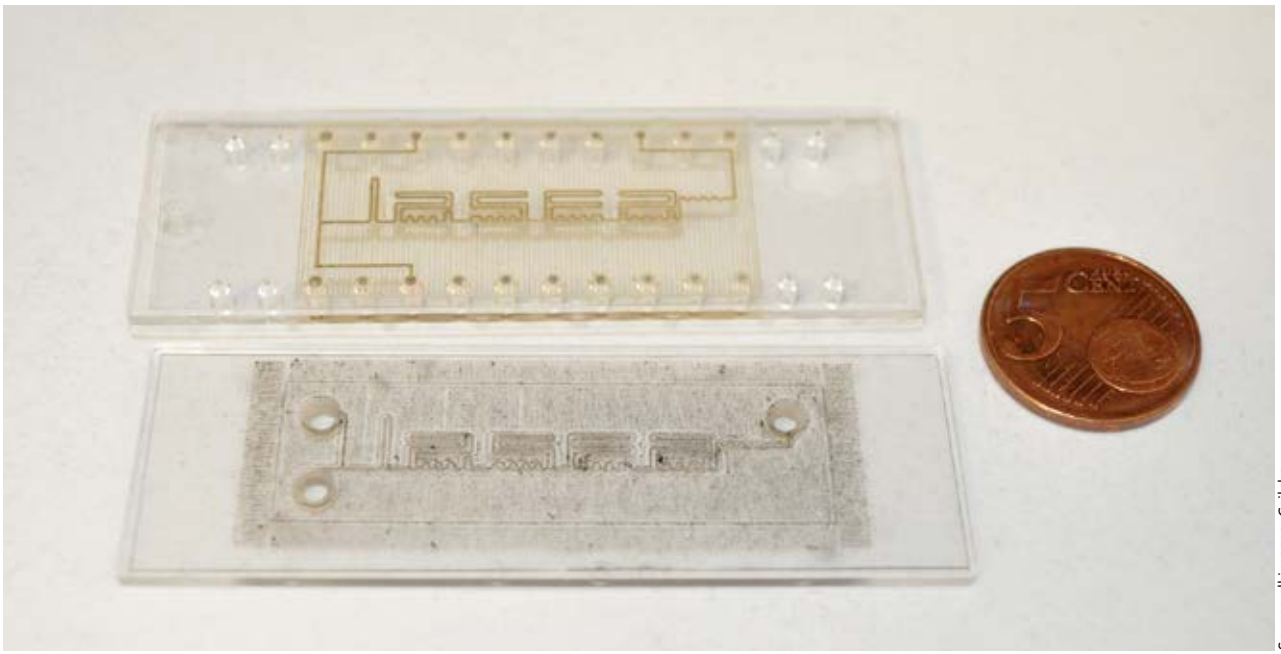
Microfluidic chip sealing using femtosecond lasers

Beam shaping improves quality and speed in laser welding processes

Julien Bayol



Source all images: Cailabs

A femtosecond laser can be used in several steps in the fabrication of microfluidic chips with flexibility and repeatability. However, it seems important to combine it with a beam shaping technique in one particular step: the sealing of the various components of the chip. Cailabs and Lasea have collaborated to demonstrate the benefits of using a custom beam profile compared to a Gaussian beam during chip welding. The results: improved quality and process speed increased nine times.

Applying beam shaping to material machining has already proven its relevance in many processes. In particular, it enables the use of the latest generation of femtosecond lasers. These offer increasingly large energy reserves: 300 W industrial lasers are now available as well as more and more R&D lasers of up to a few kilowatts of operating power. In this way, beam shaping ultrashort-pulse (USP) lasers can improve standard micromachining processes such as drilling or cutting, as well as more innovative ones such as thin film ablation or surface functionalization. Recently, two companies partnered on a more advanced application: Lasea, based in Belgium, specializes in designing machines, processes, software and modules dedicated to precision laser machining, and Cailabs, a French deep-tech company, that offers optical beam shaping solutions. This specific application is the manufacture of microfluidic chips by femtosecond laser. Lasea has been working on this subject for many years, and they specifically aim to improve the quality of the welding between the chip parts using beam shaping.

Microfluidic chips: microscopic laboratories

Microfluidics is the study of fluid flows in micrometer-sized channels. This can be for purely scientific purposes to further research into the behavior of various fluids at these small scales, or it can be for technical purposes through the development of specific applications. These are varied and sophisticated: medical analysis laboratories on a chip for the biomedical sector, known as 'labs-on-chips', the now well-known PCR tests, micro-pumps for injecting medical treatments, or even the cooling of microprocessors.

These chips are generally composed of at least two hermetically sealed plates, one of which has the channel pattern engraved on its inner side. Polymeric materials, especially PDMS, allow for the rapid fabrication of prototypes and are simple to use. Traditionally, these

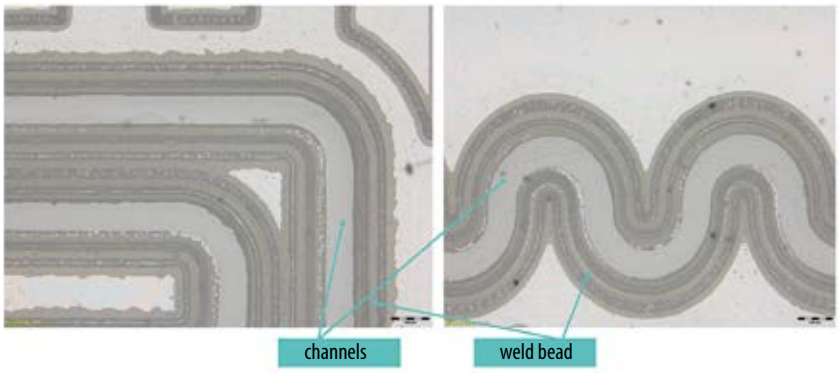


Fig. 1 Microscopic view of channels in laser-sealed microfluidic chips

chips can be manufactured in large series by plastic injection. However, this technique is not suitable for prototyping tasks, since each iteration requires the creation of an expensive new mold. For prototyping purposes, the chips are manufactured by photolithographic processes that were initially developed to manufacture semiconductors. These techniques make it possible to engrave microfluidic channels using a masking method. This process, although widespread, requires various equipment and often depends on human intervention. The plates can be sealed by thermal bonding, which tends to damage the biological material in the channels, or it can also be done by ultrasound, which requires preparing the surfaces to be welded with the presence of microstructures.

The laser therefore brings an interesting solution compared to conventional processes. The use of continuous-wave lasers has already been documented, but they require the use of black polymers, or applying an absorbing layer. This is not necessary with ultrashort-pulse lasers, which can interact with transparent materials. Indeed, this single tool can perform all the main chip manufacturing tasks: engraving channels and sealing the two wafers together. Décultot et al. have already demonstrated the feasibility of this process using a femtosecond laser source with a Gaussian profile [1]. Welding is carried out by transparency on the contour of the engraved channel, on both sides, and all along the latter, ensuring its hermeticity. The two plates must be held together with sufficient pressure and as evenly as possible during this step. This process was done for the purposes of this study using Lasea's patented electrostatic method [2]. It provides uniform and non-contact support, thereby avoiding any mechanical damage during the process. Additionally, the flexibility of the laser enables many iterations on the part design to be created, with high repeatability. Beam shaping provides an essential solution to perfect this method. A customized intensity profile was adopted to improve the quality of the welding between the two plates of the chip.

Beam shaping method

Manipulating and shaping an ultrashort pulse beam generated by a femtosecond laser is not easy. Most importantly, it is necessary to prevent chromatic dispersion and to preserve the pulse duration throughout the system. In addition, laser instabilities must be managed to avoid frequent realignment. Finally, the generated pattern must propagate through the full field of view of an F-theta lens.

The technology developed by Cailabs, MPLC (multi-plane light conversion), was therefore selected for beam shaping as it meets all these requirements. The beam shaping takes place by propagating the beam through a succession of phase plates sufficiently spaced from each other. Specifically, MPLC makes it possible to generate a spot with a very tight profile. This technology is fully reflective, so it does not impact the pulse duration. It is also possible to manage high power and energy in each pulse without any thermal effects.

With its unique modal filtering feature, the MPLC technology can also stabilize the beam. Defects such as astigmatism, ellipticity, or temporal instabilities (tilt and shift) are filtered; the shape is temporally stable. This technology performs a modal decomposition, considering these defects as higher-order modes, differentiating them from the main HG_{00} Gaussian mode. These higher-order modes follow a particu-

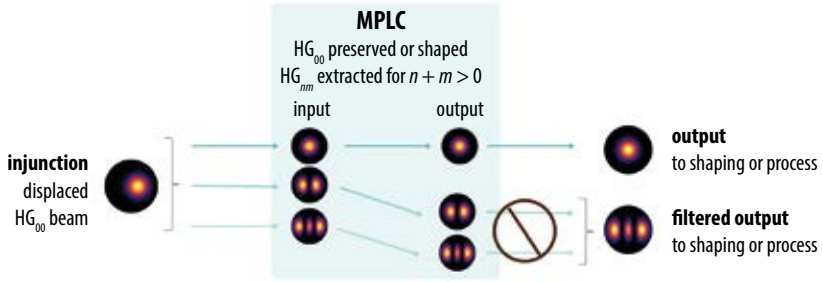


Fig. 2 Diagram of the modal filtering operation via MPLC

Company

Cailabs

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

www.cailabs.com

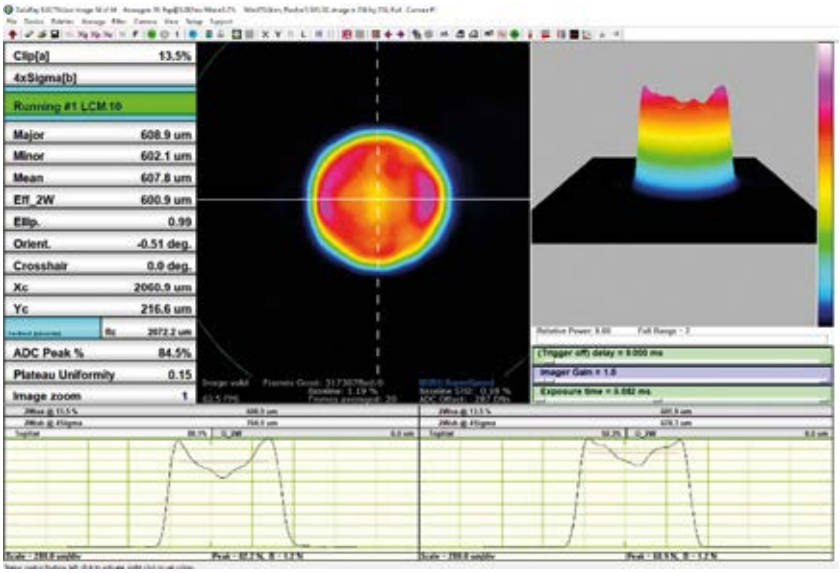


Fig. 3 Screenshot from software showing the profile of the shaped beam at the module output

lar path in the MPLC to be spatially distinct from the main shape. They are then dumped, leaving only the main mode to be shaped. This mode cleaning allows the production and shaping of a very good quality beam. However, this will impact the system transmission because the power associated with these modes is lost. So, it is subject to the quality of the beam injected at the input of the module. The transmission then depends on the quality and stability of the laser, which is typically above eighty percent.

Optical shaping and setup

After this stabilization phase, the beam is custom shaped to generate a circular U profile of 600 µm in diameter at the module output (see Fig. 3). This beam has the benefit of having a high edge sharpness, equal to 0.12. This is defined as the ratio t/L between the transition zone t of 13.5 % at 90 % of the maximum energy and the plateau length L at 90 % of the maximum energy. So the beam is about 14 times sharper than a Gaussian beam. The depth of field is also preserved (i.e. of the order of magnitude of the Rayleigh length in the working plane was measured at 2.7 mm). This is a serious advantage in terms of robustness compared to other beam shaping technologies.

The setup used to perform these welding operations is a femtosecond laser emitting at 1030 nm with a maximum allowed energy per pulse of 100 µJ. After passing through a lens with a focal length of 1000 mm at the output of the module, the beam is directed onto the part using a galvanometer scanner and an F-theta lens with a focal length of 100 mm. The circular custom beam then has a diameter of 60 µm in the working plane.

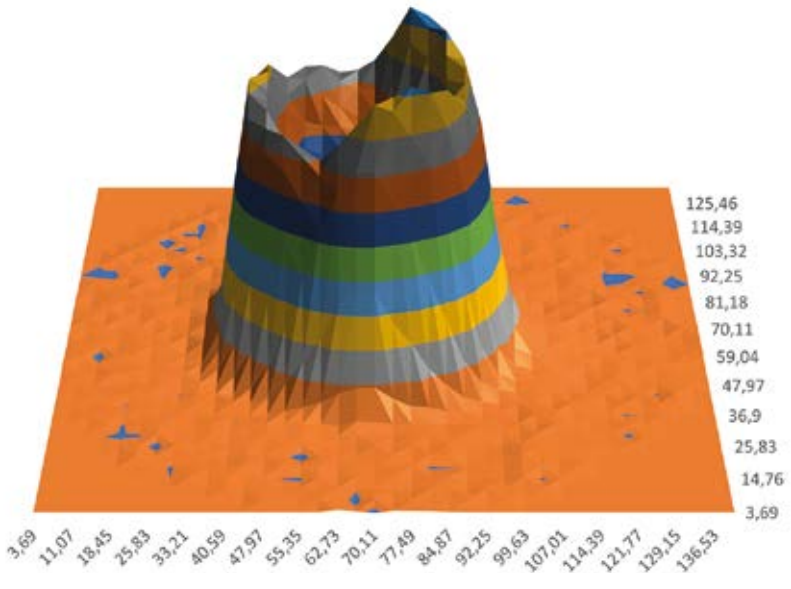


Fig. 4 Representation of the beam intensity profile in the working plane

Improved quality and 9× faster

Lasea had already conducted femtosecond laser welding tests on a microfluidic chip in a previous study, but using a raw, unshaped beam. The results showed that a strong and hermetic weld could be obtained, but also that the weld quality was not optimum. These previous results were used as a reference to compare with the results obtained from a shaped beam.

Of course, sealing the channels between each other and with the outside environment is essential in the manufacture of microfluidic chips. It is therefore important to note that using shaped beams has also resulted in strong, hermetic welds.

Using the shaped beam also brings a significant improvement in the quality of the weld. Indeed, the weld bead is much more regular. It measures on average 70 µm wide for a 60 µm diameter beam, compared to about 100 µm, with important variations, for a Gaussian beam of 14 µm diameter. Similarly, the beam shaping makes it possible to drastically reduce defects that were present in the center of the bead, such as bubbles that are now concentrated in the center of the weld bead in a regular way, or burns. Although the presence of these defects does not affect the hermeticity of the microfluidic chip, it makes it appear darker. Therefore, as a first result, the beam shaping improves the quality of the weld bead, as well as the visual aspect around the microfluidic channels.

An explanation for this phenomenon could be found in the intensity

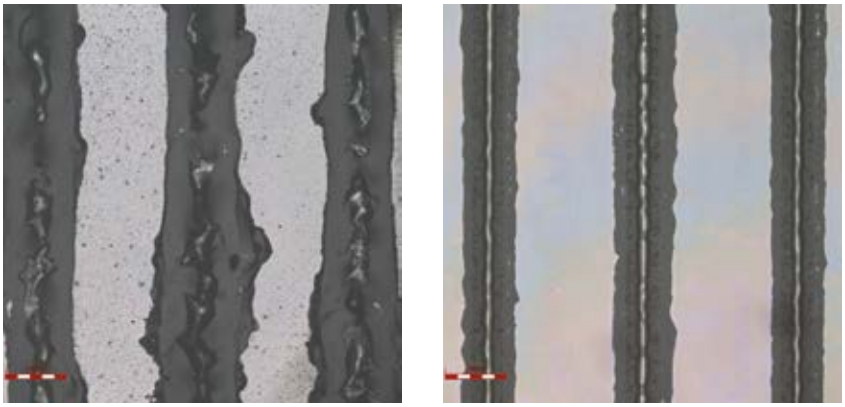


Fig. 5 Microscopic comparison between a weld made with a Gaussian beam of 14 µm diameter (left) and with the top-hat beam of 60 µm diameter (right).

profiles of the beams used. Scanning the material with the U profile results in a more homogeneous total energy. This appears in the material across the beam width, with a similar gap from the damage threshold regardless of radial position. The Gaussian profile shows a peak intensity in the center that can exceed this damage threshold, and a low intensity on the 'wings' that is wasting some of the energy since it is below the level required for welding, while still increasing the heat affected zone. This unnecessary energy peak at the center of the Gaussian beam also increases the sensitivity of the process to material inhomogeneities, making it less robust and potentially leading to the defects mentioned above. Finally, the Gaussian profile shows instabilities inherent to femtosecond lasers, while the shaped beam is stabilized.

Apart from the effects on quality, the difference in intensity profile also affects the speed of the process. It is even possible to improve the process efficiency by simultaneously increasing the energy and the scanning speed. With a Gaussian beam, a high limit was observed experimentally, preventing the increase of these parameters since it could lead to serious burns and cracks that would jeopardize the hermeticity of the chip. In contrast, the lack of an intensity peak at the center of the beam and the more homogeneous distribution with the custom profile made it possible to largely exceed the limit observed with the Gaussian beam. A custom profile can therefore process with speeds at least nine times higher, making it possible to weld a 45 × 7.5 mm^2 microfluidic chip in less than twenty seconds.

Conclusion

This study is an important step for developing new laser-based microfluidic chip prototyping solutions. Indeed, since the feasibility of this process has been previously demonstrated, it can now be optimized. The results show a significant quality improvement with less burning and bubbling, and with much more regular and accurate weld beads. Beam shaping also increases the processing speed by a factor of nine.

This study once again shows the benefits of beam shaping on laser machining processes, by applying optimal energy distribution on the material to deliver higher quality and efficiency. In our case, the adaptability of the laser is highlighted by the ability to perform multiple manufacturing tasks from the same process.

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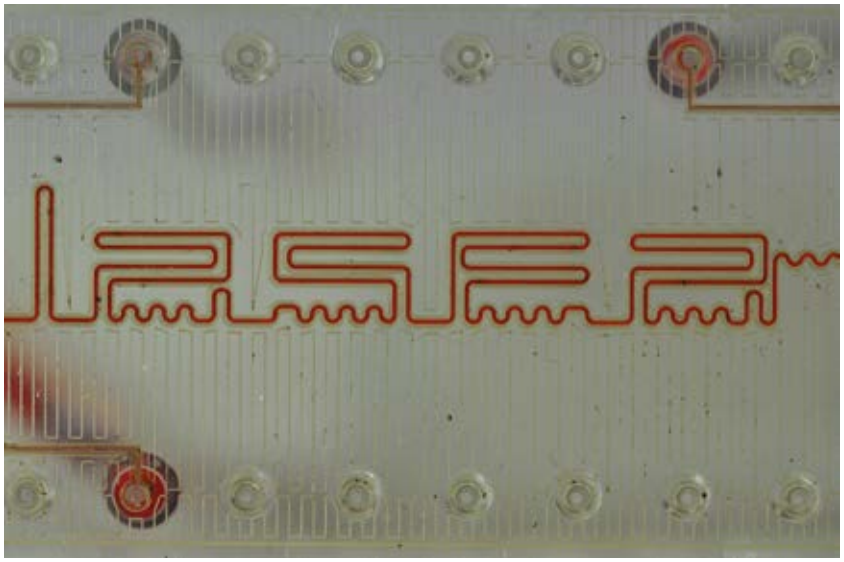

Fig. 6 Example of a microfluidic chip made with the beam shaping module, with a fluid injected inside the "lasea" logo

Author

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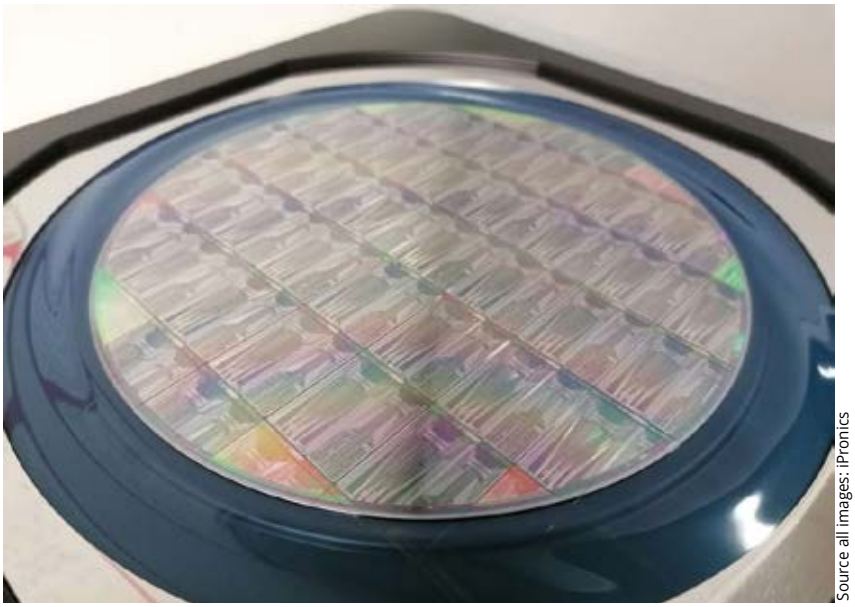
Programmable chips for 5G applications

The new generation of green and smart hardware for 5G

Ana Gonzalez and Diogo Costa

5G deployment is facing significant challenges with the need for novel technologies able to increase data density in current networks. These include antennas and radio access network (RAN) hardware, which are driven by the growing bandwidth requirements in access networks.



Source all images: iPronics

The ongoing Covid-19 pandemic has stressed the network system due to the increase in the amount of data required in booming services such as voice transfer, TV channels, video on demand and cloud services. Moreover, emerging markets such as automation in building and industrial security systems, autonomous operations in robotics, in-vehicle networking in automotive, aerospace (urban air mobility and autonomous satellites) and security (face recognition, secure bank operations …), require ultralow deterministic latency, i.e. millisecond delays for the communication across the entire infrastructure. Disruptive technologies will be key to meeting these outstanding demands.

Photonic integrated circuit (PIC) technologies

The consensus is that the introduction of photonic technologies in metro and access networks will pave the way towards the successful implementation of 5G and the future 6G technologies. Even if photonics is already omnipresent in long-haul applications, this technology is too power-hungry and too costly to be translated to the metro and access scenario where a higher number of devices are needed. Photonic integrated circuit (PIC) technology is the main candidate to meet these needs as it offers a small footprint, a reduction of cost, and CMOS compatibility, at least for silicon photonics (Si) and silicon nitride (SiN), which involves low-cost electronic packaging.

In Table 1 you can see some of the building blocks that can be integrated at chip level using PIC technology and the suitability of the main types available in commercial foundries. All kinds of building blocks can be produced using Indium Phosphide (InP), such as lasers, modulators, switches, or optical amplifiers. However, in the case of InP, losses for passive components are higher in comparison with Si and SiN. Another challenge when using InP is the packaging, since it is not CMOS compatible. In contrast, Si exhibits low losses and is CMOS compatible, so integration with electronics is straightforward. It is also possible to integrate some active components at chip level, e.g. detectors. With respect to SiN, it is the option that offers lower losses, it is the one exhibiting a smaller footprint and it is also compatible with CMOS technology. However, it is not possible to integrate active elements such as lasers, detectors or optical amplifiers. The drawbacks

building block	InP	Si	SiN
passive components	good	good	very good
lasers	very good	bad	bad
modulators	very good	good	difficult
switches	good	good	difficult
optical amplifiers	very good	good	bad
detectors	very good	good	bad

Table 1 Main PIC technologies and indicative performance of the main building blocks in optical communications.

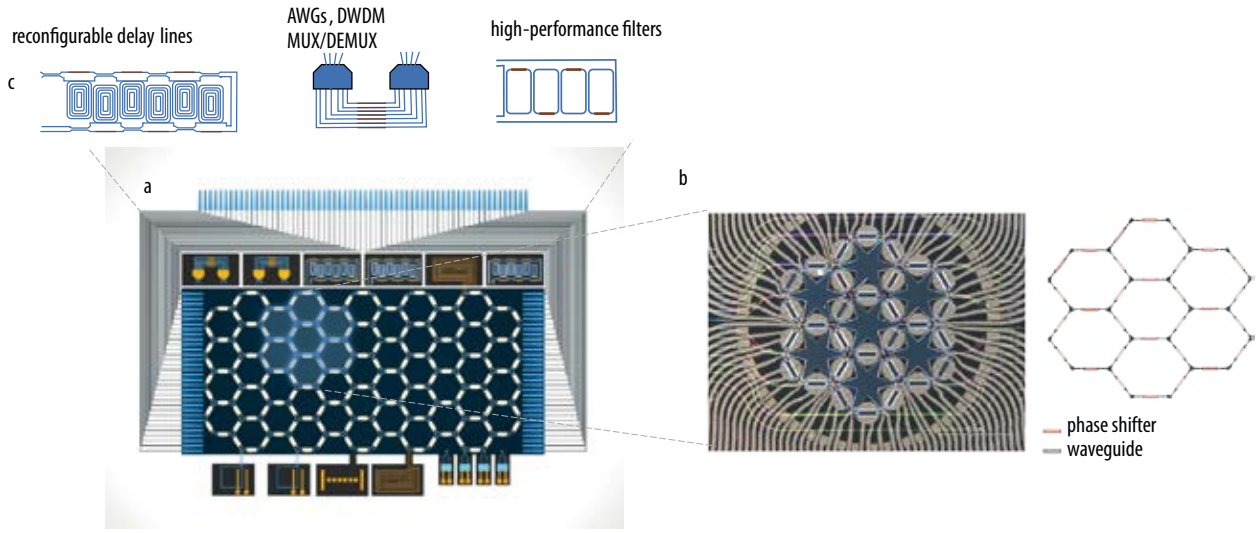


Fig. 1 The optical core of the programmable chip (a) including the Mach-Zehnder mesh (b), and the different building blocks (c).

and advantages of using the different types have driven the development of hybrid integration to further miniaturize the optical devices, where InP is integrated with Si and/or SiN.

Application-specific photonic integrated circuits (ASPICs) vs programmable PICs

Despite the numerous advantages of using PIC technology at the different levels of the optical network, there are some challenges that are hindering its adoption for the various applications, such as: i) a lack of qualified commercial foundries, ii) prohibitive prices for dedicated chip fabrication, iii) increasing development times when fabricating a multiproject wafer (MPW) run. More precisely in an MPW run, different companies fabricate together in the same wafer, sharing fabrication costs. With this solution, however, each company gets a low number of chips, which means a low number of experiments. With regard to packaging, the main challenges are related to the low tolerances involved in coupling light in the tiny waveguides.

When referring to PICs, we are usually talking about application-specific photonic integrated circuits (ASPICS), meaning that each costly and time-consuming development to produce a PIC module will turn out in a chip with a certain number of in/output ports, and a given (non-programmable) function. However, programmable PICs use a common optical hardware configuration that, employed together with the appropriate programming, enables you to implement many photonic functions with a single chip [1, 2]. This device allows different photonic analog computing operations to be performed, combined with several photonic functions in a user-friendly way and a plug-and-play system, reducing the expertise and skills required to run a PIC. A schematic representation of the iPronics general-purpose photonic processor can be seen in Fig. 1a: graphic visualization of the optical core containing the programmable mesh, the high performance building blocks and the input output connections; (1b) optical microscope image of the mesh; (1c) detail of some of the building blocks that can be connected to the mesh. In more detail, the programmable part consists of a mesh of Mach-Zehnder (MZ) devices. Each MZ has heaters in both arms, which enable independent amplitude and phase shift control. The mesh allows the user to perform processes such as linear matrix transformations and even discrete Fourier transforms in an analog way. It is also possible to add specialized performance blocks such as passive (delay lines, beam splitters …) or active (sources, comb sources and detectors …) that are connected to the mesh. The core contains the optical inputs/outputs in terms of waveguides and ports, all connected. The software controls the MZ devices, allowing the user to operate it by activating some MZs and employing the building blocks to perform different functions.

There are many advantages of using programmable PICs over ASPICS such as: i) the reduction of non-recurring engineering expense due to avoiding design rectification and iterative refinement, ii) the development of systems that are tolerant to faults and manufacturing defects, iii) self-healing and co-operative multitasking systems (redundancy approach), and iv) the ability to quickly create new photonics systems.

Applications of programmable PICs in 5G

It is possible to reduce the existing barriers to the adoption of PIC technology in many different scenarios by using programmable photonics. The first example would be radio frequency (RF) photonics or microwave photonics. RF photonics explores the generation, transport, manipulation, and detection of high-speed RF signals. An integrated RF photonics chip is composed of a laser light source, an optical modulator, an optical signal processor and a photodetector (Fig. 2). An input RF signal with frequency f_{RF} is acquired from an antenna or an RF source and modulates the output of an optical source to upconvert its spectrum into optical frequencies. This typically forms a pair of sidebands at frequencies $\nu \pm f_{RF}$, where

Company

iPRONICS

iPRONICS developed 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 the Internet of Things.

https://ipronics.com

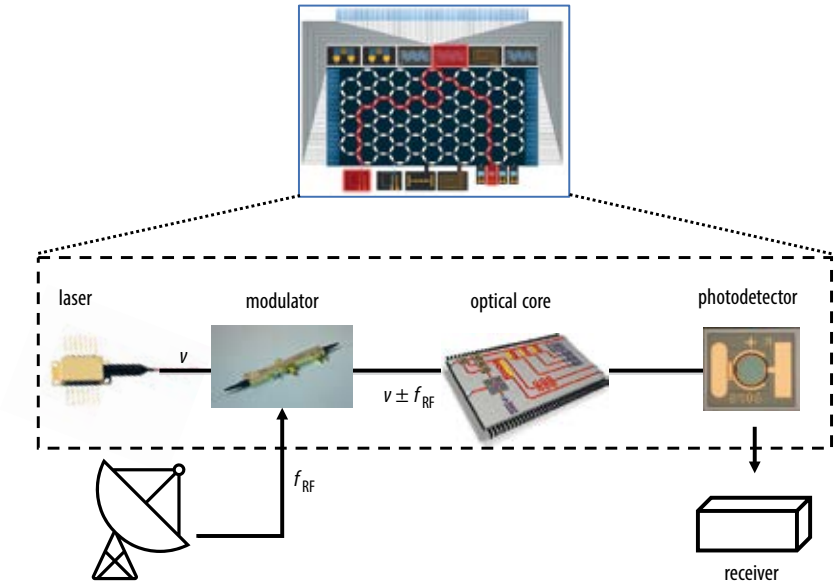


Fig. 2 A microwave photonic device able to transform the RF signal in the optical domain where the entire optical part can be replaced by a programmable chip that includes all the necessary functions.

v is the central frequency of the optical source. The combined optical signal is then processed by an optical system composed of several photonic devices forming an optical signal processor, which modifies the spectral characteristics of the sidebands. Finally, an optical detector is employed to downconvert the processed sidebands by beating with the optical carrier, so that the processed RF signal is recovered. As indicated in Fig. 2, a single programmable chip can integrate all the required and bulky devices such as the laser, modulator, processor, and detectors. In addition to the miniaturization capabilities, a single programmable chip could be used for different functions such as filtering, true-time delay lines, phase shifting, frequency up and down conversion and microwave signal generation. In the case of electrical operation, a microwave signal is generated using an electronic oscillator with many stages of frequency doubling to generate a signal with the desired frequency. But with frequency multiplication, the phase noise performance of a microwave signal would be degraded by 10 $\log_{10} M^2$, where M is the multiplication factor. Microwave photonics, on the other hand, allows direct synthesis of RF from the optical domain, opening the path to the generation of very high frequencies with low phase noise.

Another application area where programmable photonics can provide high performance devices is optical switching. An optical switch is a multiport network bridge that connects multiple optic fibers to each other and controls data packet routing between inputs and outputs. Currently almost all optical switches perform an electrical conversion by converting light to electrical data before forwarding it and converting it into a light signal again. But there are other optical switches, called 'all-optical', that can route and forward the light pulses without any electrical conversion. An all-optical switch controls the routing between multiple optic fibers without any electrical data conversion, so it neither converts nor alters level data packets. Consequently, all-optical switches do not have latency, data corruption or timing jitter – a tendency to lack synchronization, caused by mechanical or electrical changes – and they present broadband operation. So far, the most commercialized all-optical switches are based on micro-electromechanical systems (MEMS) technologies. MEMS-based optical switches consist of complex movable 3D mechanical structures, microactuators, and micro-optics that can be monolithically integrated onto the same substrate. These devices present different drawbacks such as stiction (permanent attachment of the suspended microstructures to the substrate or to each other), fatigue (which refers to the application of alternating or repeating loads lower than the static strength of the device, leading to a steady degradation), creep (permanent deformation due to repetitive operations at high temperature), the presence of residual stress, distortion, stress corrosion, and dimensional stability to name a few.

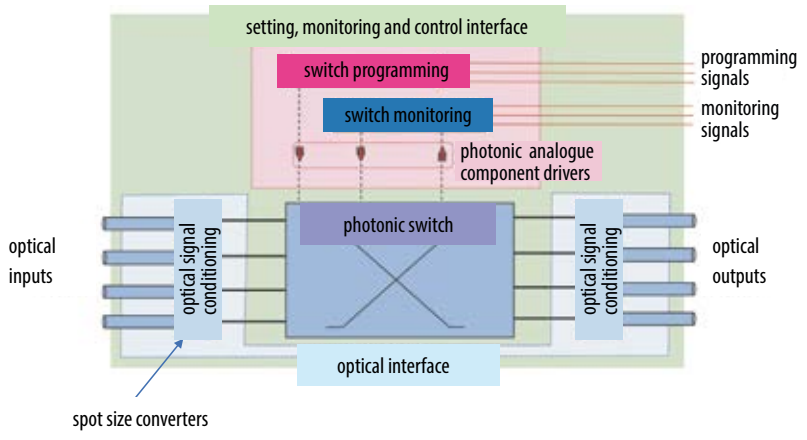


Fig. 3 A diagram of an all-optical switch based on a programmable photonic integrated circuit device.

The alternative for all-optical MEMS based switches is the use of PICs or, even better, the use of programmable PICs. First of all, the use of PICs will allow the development of systems with high stability as all the components are in the same platform without moving parts. In addition, the use of programmable PICs will allow the development of a reconfigurable switch, including cross-connect, point-to point, point-to-multipoint, broadcast and multicast operation. In addition to the connections to control the independent MZ devices

in the core, for the development of this all-optical switch (see Fig. 3), this core must be connected to two external elements: the electrical setting, monitoring and control interface and the optical interface. The monitoring and control interface takes electronic control signals for programming purposes and to collect feedback regarding their operation points and provide corrective signals if required. The optical interface contains all the necessary optical inputs and optical outputs to operate the optical switch. In the case of switching modules, input signals are usually digital, so drivers can be basically digital-to-analog converters.

Conclusions

The main challenges in a metro-network are related to the lack of photonic technology that is able to process the data in the optical domain while offering more bandwidth and less power consumption, at a relatively low cost. In terms of cost reduction and increasing the density of functions, PIC technologies are the most suitable candidates for being employed in 5G applications. In addition, reconfigurability and the ability to perform multiple tasks are key in many functions such as RF photonics and optical switches, indicating a promising future for programmable photonics in the present and the future 5G of optical communications.

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Diogo Costa is an internationally experienced scientist with multiple research interests in advanced technologies, including spintronics, photonics and neuromorphic hardware. Diogo has made more than forty scientific contributions to international journals and congresses. Prior to joining iPronics, Diogo had an industry-facing role at IMEC (Interuniversity Micro-Electronics Center) in Belgium, acquiring multiple contacts with semiconductor companies and tool suppliers. He received his PhD from the International Iberian Nanotechnology Laboratory (INL) and BSc/MSc degrees in physics from Porto University, Portugal.

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LiDAR and autonomous cars: no conventional solution

TOF lidars are recognized as the norm, but FMCW systems are increasingly growing in popularity

Florian Friedl

Source: Getty Images/RooM RF

Which is the best lidar technology for automotive applications? There is still no such thing. As a leading component manufacturer, Hamamatsu is well aware of the advantages and disadvantages offered by various systems, and the main differences will be explained in this article.

Whether in factories or cars, the use of smart and autonomous systems is increasing. An important condition for totally safe and functional systems is sophisticated sensors and imaging processes that provide true-to-life images of the surroundings. Advanced driver assistance systems (ADAS) currently employ around a hundred sensors to provide functions such as lane departure warning or automatic distance control. Full accuracy and fast reaction times are essential in this field, even at high speeds and in unforeseen situations.

One of the most promising developments in recent years has been the use of light detection and ranging (lidar) systems, an optical method to measure distance and speed. Unlike the related radar system, lidar sensors identify the environment by means of light only, which is detected by a photosensor. But not all lidar systems are the same, and not all photosensors are equal. Which technology is the most suitable is not always clear to the manufacturer and depends on the specific application.

Hamamatsu Photonics, a manufacturer of optical products and semiconductor components, helps to select and assemble the right components as the company's products cover the entire range of lidar technologies.

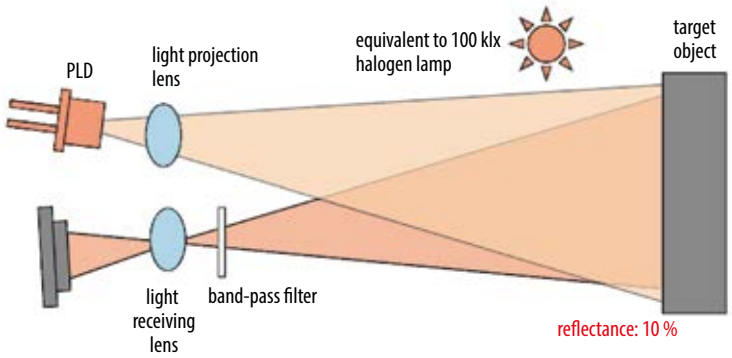
TOF measurement or FMCW?

There are currently two technological approaches to lidar: time of flight (TOF) and frequency-modulated continuous wave (FMCW), which is based on frequency modulation. While TOF lidars are recognized as the norm, FMCW systems are increasingly growing in popularity for reasons such as the promise to overcome some of the problems of the time-of-flight approach.

Time of flight: round trip for light

The basic principle of TOF lidar is simple: a light source emits a concentrated beam of light that is reflected by an obstacle – such as a pedestrian or a car – and bounces it back to a photosensor. The sensor calculates the distance of the object, based on the time needed by the reflected light to hit the sensor.

Pulsed lasers are often used as a radiation source, which allows the wave-



Lidar concept (Source: Hamamatsu Photonics)

length and polarization state of the pulse to be varied. Commonly, wavelengths ranging from 850 to 1,550 nm are used.

Lower wavelengths allow the use of silicon detectors, but the light is absorbed more easily and they are more harmful to the human eye, consequently they are not suitable for all applications. Light with a wavelength of 1,550 nm is also the only one that provides reliable results. It is better suited for long distance detection and can produce accurate results even at a distance of more than two hundred meters with a reflection of ten percent.

One challenge of TOF technology is the scattering of the light: only a small fraction of the emitted photons find their way back to the active area of the photosensor. Environmental influences, such as rain or air particles as well as other reflective surfaces, absorb some of the light and reduce the number of photons received. At the same time, photons related to background noise hit the detectors, which can negatively influence the accuracy of the measurement. A filter that is strictly limited to the range of the emitted wavelengths may help, but this background noise cannot be completely prevented, meaning that the accuracy of the lidar reduces with increasing distance.

FMCW: measurement by modulation

One method of reducing this problem of interfering frequencies could be FMCW lidar: instead of light pulses, a continuous, 'chirped' laser beam is emitted, so the frequency of the signal keeps changing. The light beam is reflected by an object and returned to the photodetector. The decisive factor here however is not the time itself, but the difference in the frequency of the incoming signal compared to the signal emitted at the same moment. Based on this difference, the lidar can determine not only the distance but also the speed of the moving object.

Frequency synchronization requires a bit more computing power than a simple acquisition. Compared to TOF, the FMCW method takes a little more time to create an accurate 3D environment model. Moreover, the technology is also relatively new and consequently often still bulky and expensive. On the other hand, FMCW lidars are less subject to noise and work well over long distances. So the question about the 'best' lidar technology largely depends on the application scenarios and the prevailing conditions. The choice of method is important, but there is another key consideration: the selection of the optimum photosensor.

Photosensors: accuracy vs range?

Lidar applications have high expectations of photodetectors. Ideally, they should be sensitive enough to receive a large number of photons without collecting too much extraneous noise. In automotive applications in particular, it is also essential that the sensors respond quickly and with full reliability. They should also be cost-efficient, suitable for mass production and able to tolerate a whole range of different environmental conditions, from temperature fluctuations to changing light conditions.

In any case, the greater the distance from the object to be detected, the lower the measurement accuracy. This principle is not equal for all types of photodetectors however. Depending on the application, manufacturers can in fact choose from these three types of photosensor.

PIN Photodiode

A PIN diode – which has a wide, undoped, intrinsic semiconductor between the p and n regions – is the simplest and most cost-effective type of photosensor. Energy consumption is also low, with an operating voltage of up to ten volts. Over short distances, the light sensitivity is high and stable at the same time, and temperature fluctuations hardly affect the performance. The readout range is relatively high and even in strongly illuminated surroundings a PIN photodiode usually performs well. A transimpedance amplifier is usually used as the readout circuit. However, the gain is low, typically around one.

In the case of applications where the light does not have to travel long distances – for example some TOF applications – the use of a PIN photodiode is absolutely sufficient and offers manufacturers the best price/performance ratio. For example, the S13773, a Si PIN photodiode from Hamamatsu Photonics, is suitable for distance measurements in the spectral range 380 to 1,000 nm due to its fast response time, but it is not appropriate for conditions that require wavelengths of 1,550 nm. Applications with strong ambient light or significant temperature changes also benefit from

Company

Hamamatsu Photonics Deutschland

Hamamatsu Photonics is a Japanese manufacturer of optoelectronic detectors, light sources and systems. The company was founded in 1953 in Hamamatsu City, where it is still located for research and production today.
Hamamatsu Photonics is one of the world's leading innovators in photonics; it develops and produces components across the entire range of light-based technologies and is a leading high-tech supplier for a wide range of industries such as chemical analysis, medical, automotive, security, X-ray and sensor technology.
The Systems division produces a wide range of image processing systems used in life sciences, digital pathology, semiconductor manufacturing, process control and basic research.

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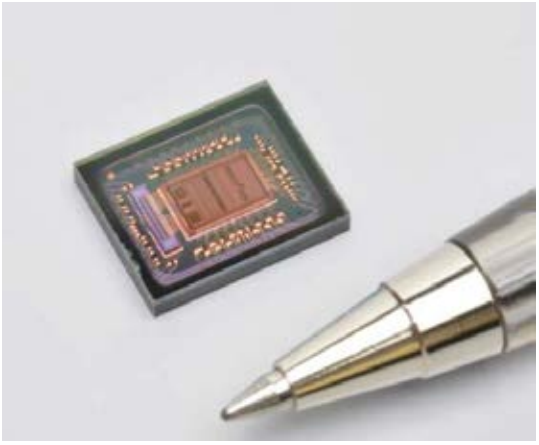
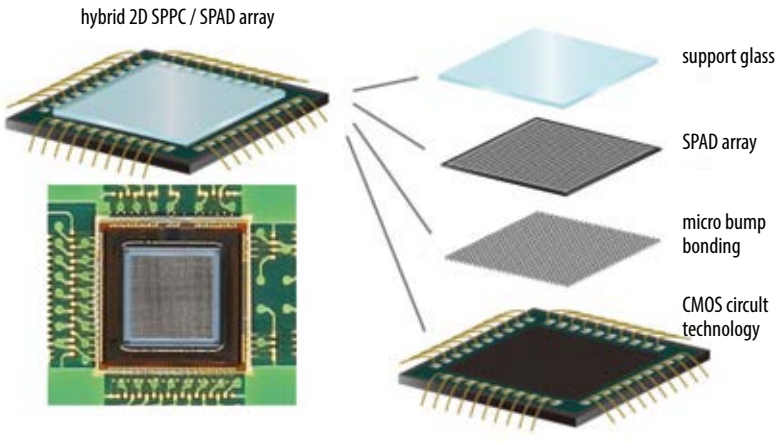


1D MPPC (SiPM) Array + ASIC (Source: Hamamatsu Photonics)



Hybrid single-photon avalanche diode (SPAD) array (Source: Hamamatsu Photonics)

using a PIN photodiode. The S13773, for example, can tolerate operating temperatures between -40 and +100 °C.

Avalanche photodiodes

As the name suggests, avalanche photodiodes (APDs) use the avalanche effect to generate internal gain. This achieves gains of over one hundred, a greater range than PIN photodiodes. However, in order to prevent measurement inaccuracies from the background noise, manufacturers usually resort to a bandwidth filter. APDs are also very temperature sensitive and have an operating voltage of 100 – 200 V. In addition to Si APDs, there are also special InGaAs APDs that are specifically designed for a wavelength of 1,550 nm (e.g. Hamamatsu's G14858-0020AB).

For a long time, these two variants have been considered standard devices for their respective fields of application. Although APDs are more complex and expensive compared to PIN photodiodes, they are almost indispensable for longer-range applications. Nevertheless, Hamamatsu has recently brought a third candidate into the race: so-called multipixel photon counters (MPPCs).

Multipixel photon counters

MPPCs, also known as silicon photomultipliers (SiPM), consist of a series of APDs (hereafter referred to as channels) operating in Geiger mode. As a result, an MPPC sensor has significant gain – up to a factor of 10^5 is easily achievable. At the same time, the use of several APDs connected in parallel prevents a loss of information about the number of incident photons. MPPCs are therefore also suitable for single-photon detection and can cope with suboptimal conditions with very weak light incidence. They provide reliable results, even at long distances, granting a short response time. MPPCs are also insensitive to magnetic fields and, in terms of temperature sensitivity, they qualify between APDs and PIN photodiodes. Moreover, while MPPCs can be switched via a transimpedance amplifier just like PIN photodiodes or APDs, it is possible to utilize less complex readout circuits, such as high-frequency amplifiers.

In Hamamatsu's new generation of MPPC detectors, the photon detection efficiency (PDE) has been further improved. This combination of features makes MPPC sensors an attractive alternative for many automotive applications that could previously only be covered by APD sensors. In addition to MPPCs, Hamamatsu will soon introduce 2D SPPC arrays. As with MPPCs, these 'single-pixel photon counters' can cover long-range sensing and have similar detection speed and temperature stability characteristics. The overall system costs could be cheaper than the costs of MPPC modules.

It is then worth pointing out: the road to fully autonomous industrial and automotive applications is rocky and deeply ramified. Individually adapted solutions are key to dealing with this complexity, and the motto "customizations instead of standard solutions" could not apply better to lidar systems. As a one-stop-shop, Hamamatsu can offer both unbiased opinion and advice. They can also supply all components from a photodetector to a laser diode, all from a single source. They can offer pulsed lasers as well as continuous wave lasers with a very accurate near field pattern (NFP). All components are perfectly adapted to one another and can be adjusted to the requirements of each individual application.

*

Text in cooperation with Nina Blagojevic, Storymaker GmbH.

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Florian has successfully managed several innovative automotive projects from R&D to SOP, through to mass production. One of his current points of focus is the automotive lidar market, where he has built up his expertise in a range of different sensor technologies.

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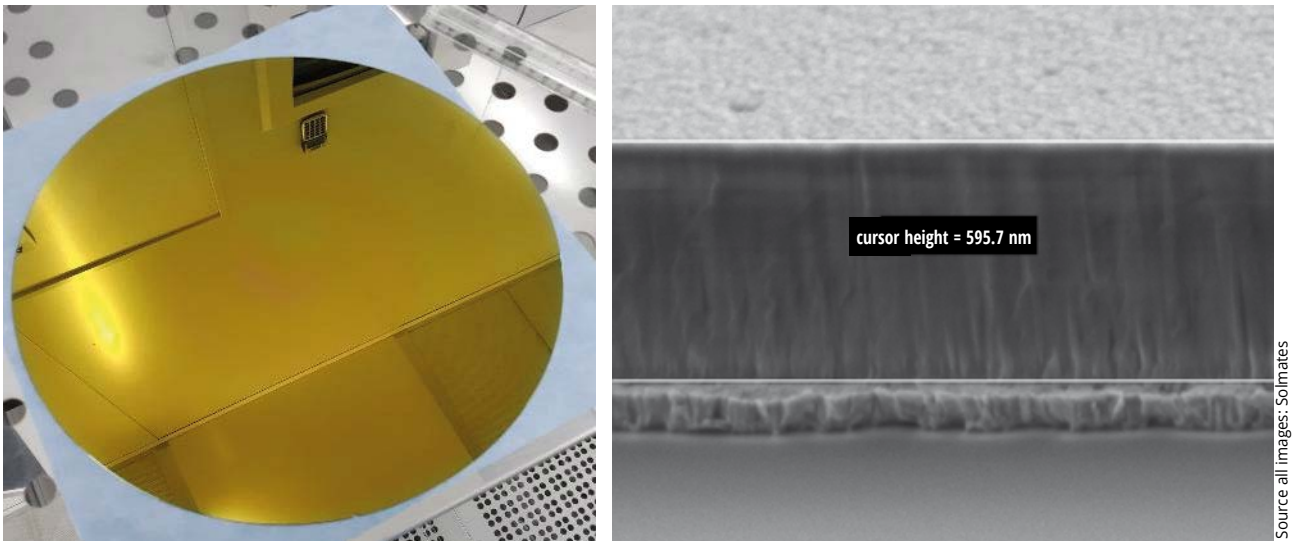
*) currently on parental leave, use info@hamamatsu.de instead

Pulsed laser deposition – materials that matter

Scalable, modular PLD systems drive high volume production of game-changing functional layers

Ralph Delmdahl, Lennart de Vreede, Bart Berenbak, and Arjen Janssens



Source all images: Solmates

Pulsed laser deposition (PLD) is the thin film method of choice for depositing complex oxide films and highly textured epitaxial layers with unsurpassed crystallinity. Excimer laser power scalability and PLD process upscaling have resulted in the first systems with 300 mm wafer capability now entering the market. From mobile communication to autonomous driving, novel materials available to high-tech volume manufacturing matter in transitioning into a 5G connected future.

Piezoelectric aluminum nitride (AlN) thin films are mass-manufactured on wafers at great numbers exceeding a billion units per year. They are in use as film bulk acoustic resonator (FBAR) discrete radio frequency (RF) filters in smartphones. The advent of the 5G era as well as next generation wireless communication standards require filtering more and higher frequencies and thus ever thinner AlN films. However, the thinner the AlN film, the less piezoelectric they are which sets an upper frequency limit. As a solution to this catch, the piezoelectric response can be greatly enhanced by doping the AlN thin film with scandium. Depositing ScAlN with high dopant via co-sputtering using different targets is associated with extra costs and process control complexity. On the other hand, large alloyed ScAlN sputter targets are costly, brittle and prone to crack formation.

Employing the PLD method and excimer lasers with a wavelength of 248 nm, not only small and affordable ScAlN targets (Scanramics by Solmates) can be used but they can also contain >40 % scandium for depositing high quality films and achieving optimum piezoelectric response. Using the Scanramics target, high density, 600 nm ScAlN piezoelectric thin films on 200 mm silicon wafers have been successfully deposited with high quality. Expanding the scanning pattern is the only step between 200 mm and 300 mm wafers (Fig. 1) because the thin film deposition is performed by a scanning motion of the wafer.

▲**Fig. 1** 300 mm silicon wafer with homogeneous PLD thin film using an excimer laser at 248 nm (left), cross section of a 600 nm thin piezo-active scandium-doped aluminum nitride (ScAlN) layer on a platinated silicon wafer (right)

Building blocks enable stepwise system throughput scaling

A modular PLD system design concept is key to facilitate the critical path from thin film development to pre-production, and ultimately to high-volume manufacturing using the same technology platform. The scalability of 248 nm excimer laser technology from Coherent over a wide a range of power levels extending from 80 W to 300 W is essential to align the system investment with the actual throughput needs.

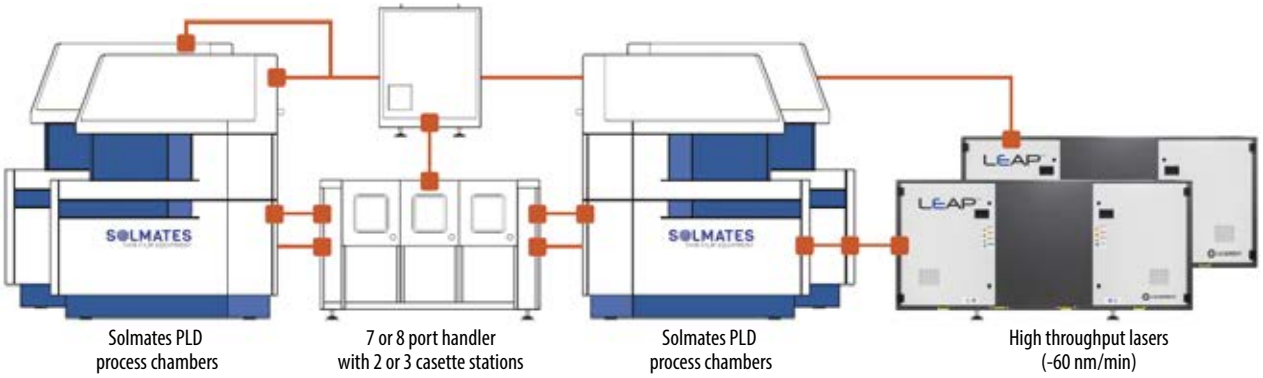


Fig. 2 Multichamber Solmates PLD system for high volume thin film production based on the Coherent LEAP excimer laser series

A pilot production system based on one Solmates PLD chamber and one Coherent 100 W LEAP laser enables a throughput of 25 or 75 wafers per day depending on the decision to use a four-port handler with one cassette station or a six-port handler with two cassette stations respectively.

With a modular system architecture, more PLD chamber modules and excimer lasers can be added and controlled to ramp up from volume to high-volume manufacturing. With the modules shown in Fig. 1, the throughput can be scaled to volume production of up to 300 wafers per day, orchestrating four PLD process chambers powered by two 300 W LEAP excimer lasers.

As an important prerequisite, Solmates PLD systems are fully automated with industry standard, SEMI-compliant automation software that is mandatory for batch processing of advanced recipes. Compliancy with industry standards for wafer-to-wafer variation, wafer tracking and logging analysis is also ensured. The SEMI-compliant software is customizable to integrate with common cluster main frames and supports SECS/GEM and GEM300 host connectivity. Each PLD chamber can be equipped with a manual load-lock, a Standard Mechanical Interface (SMIF for 200 mm wafers) or a front-opening unified pod (FOUP for 300 mm wafers) handler or an advanced cluster frame for process ramp-up. The same PLD chamber can therefore be used for process development and later expanded by adding more PLD chambers (Fig. 2).

Expanding the scope of materials

Classical deposition methods such as spin coating or sputter techniques are well established, yet they reach their limits when it comes to more complex thin film compositions.

PLD is a physical vapor deposition method that uses highly energetic laser light to energize material, creating a deposition plasma that can be condensed on any possible substrate. The controllable density and kinetic energy of the species inside the plasma leads to the formation of metastable material phases that are associated with supersaturated film growth. This gives PLD a competing edge when it comes to material nucleation at the substrate interface. The result is high crystallinity film growth with near-perfect epitaxy even at lower deposition temperatures, starting right from the first few nanometers. Next to film density control, soft-landing or low interface damage conditions for the transferred atoms in the plume can also be chosen, which accommodates deposition on particularly sensitive substrates. As PLD does not require any bias applied to the substrate or target, the technology is a very suitable deposition method for thin film growth onto different conducting and non-conducting substrates. The use of reactive and inert gases inside the vacuum chamber enables tuning of the deposition kinetics as well as the film stoichiometry. The localized plume can even be used to obtain predetermined stress-profiles of a thin film across the

Companies

Coherent

Founded in 1966, Coherent Inc. is one of the world's leading providers of lasers and laser-based technology for scientific, commercial, and industrial customers. With headquarters in the heart of Silicon Valley and offices spanning the globe, Coherent offers a unique and distinct product portfolio and services that include instrumentation, microelectronics, and materials processing.

www.coherent.com

SOLMATES

Solmates is a fast-growing equipment supplier of thin film deposition tools based on high power LEAP lasers from Coherent. The company started in 2007 as a spin-off from the MESA+ Institute for Nanotechnology, located at the Science Park Twente in the Netherlands.

Since 2020, Solmates has been scaling up production of its unique pulsed laser deposition (PLD) equipment to supply high-volume manufacturing equipment to different thin film markets worldwide. The team consists of highly respected specialists, combining highly recognized scientific knowledge and a track record with well-established semiconductor companies.

Solmates develops and sells unique PLD equipment to semicon manufacturers, providing superior quality wafers at a fraction of the cost. As a fast-growing OEM company, our mission is to position PLD as a mainstream thin film deposition technology equal to ALD and sputtering.

www.solmates-pld.com

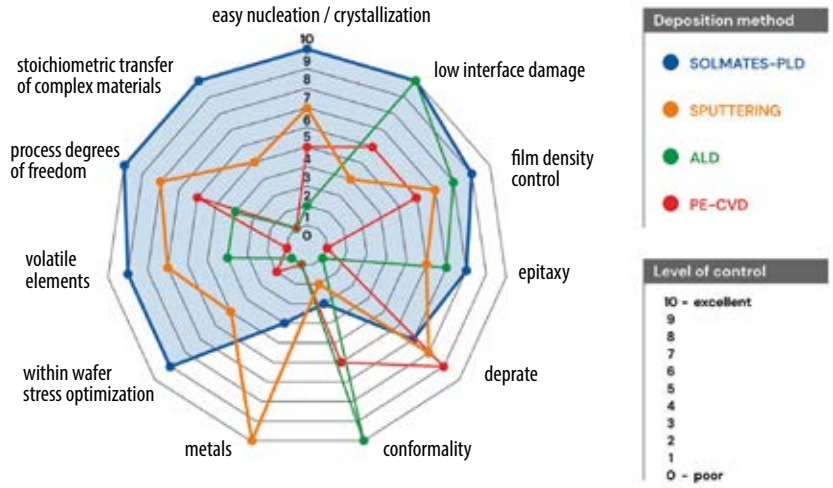


Fig. 3 Qualitative comparison of industrially relevant process parameters achievable with standard thin film production methods

wafer area to compensate for adjacent layers in a device stack.

Fig. 3 shows the comparison of mainstream industrial, thin film manufacturing methods with respect to their level of deposition control. While each deposition method has its specific advantages, PLD obviously extends the scope of complex thin films and facilitates the use of a wider range of substrates amenable to being coated. Scalable excimer laser power and PLD system modularity therefore accelerate the entry of novel materials into commercial products required by next technology nodes, of which 5G RF filters are one of the most prominent examples.

Next to the superior capabilities of PLD as a truly unique technique to grow complex functional thin films which cannot be obtained otherwise, scalability both in substrate area up to 300 mm wafer sizes and film deposition rate is pivotal to serve any industrial application. Also, core innovations together with constant performance and lifetime improvements have rendered excimer lasers the most cost-effective and dependable pulsed ultraviolet (UV) laser technology for thin film applications. Over the last decade, PLD system design as well as excimer laser power levels have evolved from thin film labs to viable and reliable high-volume deposition equipment on the industrial production floor. As a matter of fact, pulsed laser deposition today has evolved into an economical breakthrough technology, pushing the material performance envelope in several high-tech industries such as the desperately needed 5G RF filter devices.

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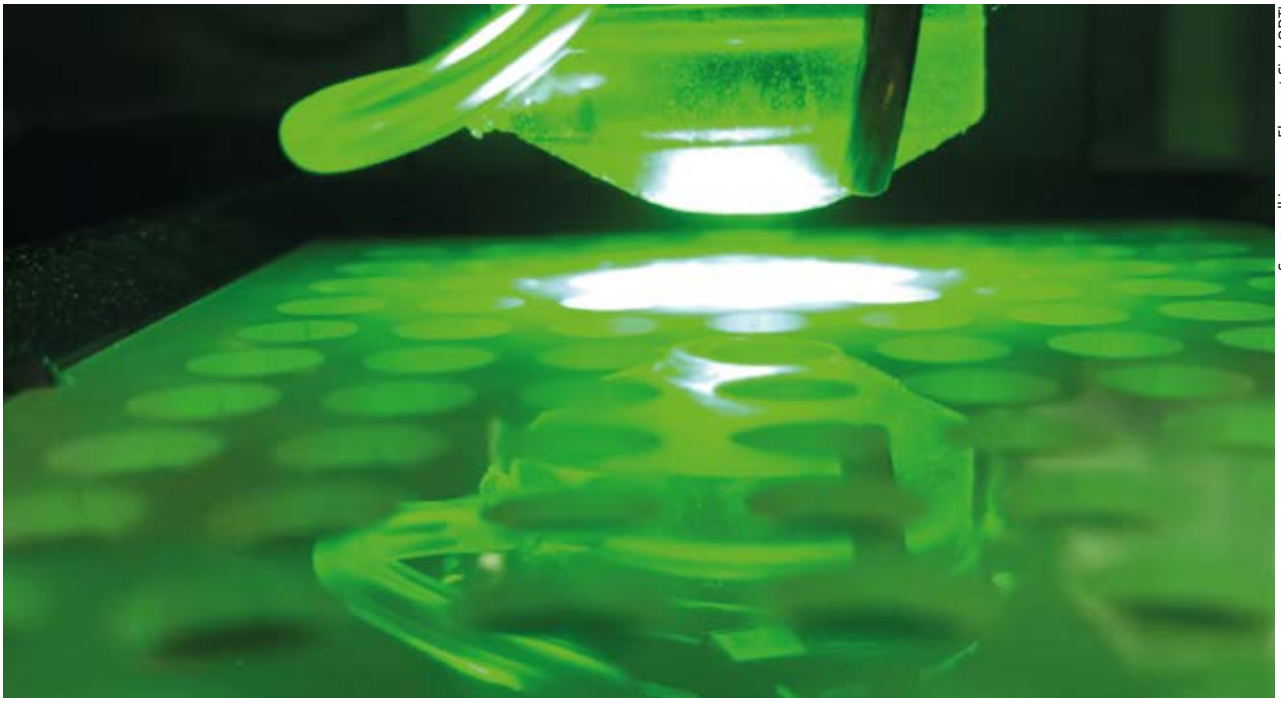
Quantum diamond biomarker detection

Targeting simpler, faster and ultrasensitive medical diagnostics



Source all images: Element Six / QDTI

A successful research collaboration between Element Six and Harvard University's spin out Quantum Diamond Technologies Inc. (QDTI) aims to disrupt the medical diagnostic market by revolutionizing the early detection and treatment of diseases.

QDTI is a start-up founded by researchers from Harvard University with the aim of leveraging the powerful properties of quantum spins in diamond to significantly improve the early detection of diseases. A close and long-standing collaboration with Element Six has been integral to the development of QDTI's technology, which relies on a multilayer diamond material solution powered by nitrogen vacancy (NV) centers for enhanced sensing.

The company's goal is to deliver a very simple-to-use, rapid, point-of-care diagnostics platform to enhance patient care for medical conditions such as heart disease, Alzheimer's disease, and cancer. Patient outcomes greatly benefit from the detection of disease-specific biomarker molecules at an early stage. Based in Massachusetts, QDTI has secured funding, among other sources, from DARPA, the Michael J. Fox Foundation and the Bill and Melinda Gates Foundation, and is currently working with pharmaceutical companies in the biomedical research and development testing space.

The opportunity: early disease detection

For many diseases, early detection is vital to enabling effective treatment programs and improving patient outcomes. Fortunately, early disease detection and diagnosis can be achieved through the measurement of biomarkers such as proteins, nucleic acids and cells in a blood or saliva sample from the patient. The industry standard to measure these biomarkers is to bind the analyte of interest with a tag, such as a florescent marker, or an enzyme that acts upon the addition of a substrate to reveal a colorimetric signal. The concentration of the disease biomarker in the blood, for example, is determined by comparing the optical signal intensity against a standard curve. Such analog measurements, while not sensitive at the single-molecule level, have nevertheless been versatile and robust enough to support a global testing market worth well over 25 billion dollars annually.

The challenge: the need for a simpler, more accurate detection method

Ultrasensitive protein detection methods are required to detect several diseases or disorders such as heart conditions as early and accurately as possible. However, immunoassays with fluorescent or colorimetric tags suffer from unwanted background due to auto-florescence from extraneous

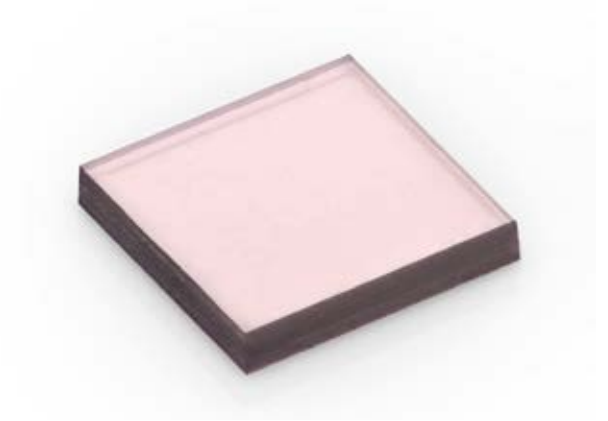


Fig. 1 Award-winning Element Six DNV™ B1 – the first commercially-available, general-purpose quantum grade diamond

Fig. 2 QDTI benchtop immuno-assay detection instrument

biomolecules or reagents, which can limit the sensitivity of the immunoassay. A lengthy sample processing procedure is therefore necessary to remove the background before accurate measurements can be made. The required sample processing directly translates for patients into a longer time to wait for the results.

The solution: diamond nitrogen vacancy magnetometry

QDTI is able to harness the unique properties of diamond nitrogen vacancy (DNV) by labeling the target biomarker in a patient's sample with a magnetic tag rather than a florescent or colorimetric tag. Once this step is complete, the quantum diamond solution allows for direct, digital quantification of labeled targets through magnetic imaging of the now-tagged disease biomarker on the diamond surface. This provides a high resolution and allows for the elimination of cumbersome sample processing steps. By optimizing the concentration and placement of the NV centers in the diamond, QDTI has demonstrated single-event spatial resolution with wide-field DNV magnetic microscopy over a field-of-view of ~1 mm^2. This enables ultrasensitive protein quantification in under an hour, in contrast to the many hours required by commercial platforms in the research market segment.

Thanks to QDTI's innovation, combined with Element Six's diamond manufacturing and engineering expertise, new and simpler methodologies for isolating and counting key biomarkers at high sensitivity are now feasible in smaller hardware systems with improved time to results. QDTI estimates that its platform could lead to at least a 90 % reduction in technician hands-on time as well as greatly reducing the volume of reagents and disposables required to process the patient's sample. The resulting benefit will be faster diagnosis times for patients at significantly lower cost, as well as a more environment-friendly product.

> "When your technology is as disruptive as ours, you need someone you can trust to support you and help solve your technical challenges. The NV centers in high purity diamond from Element Six are the workhorse of QDTI's technology."
>
> John Pena, CEO QDTI

Leveraging its successful collaboration with Element Six, QDTI is currently developing a new commercial immunoassay detection system powered by Element Six's NV center-enriched diamond, coupled with high value immunoassays. The product will initially target the biomedical and research markets, with the objective of a commercial launch expected early 2022. Element Six and QDTI are also currently exploring methods to refine the NV performance and manufacturability to further reduce the protein quantification time.

Why diamond

DNV magnetometry surpasses all other technologies for high-throughput, high-resolution imaging of microscopic magnetic signals. CVD-grown diamond sensors can image millimeter-scale areas with sub-micrometer resolution and exceptional sensitivity, collecting data from millions of pixels simultaneously in a few seconds. Unlike conventional magnetometry methods, there is no need to scan a probe over each pixel, manage electrical connections to many sensors, or operate under vacuum or extremely low temperatures. Instead, the entire image is read out at once through

Companies

Element Six

Part of De Beers Group, Element Six is a pioneering manufacturer and supplier of diamond synthesized to contain NV centers using the chemical vapor deposition (CVD) method. Working with researchers and commercial companies around the world, Element Six has developed, manufactured and supplied the world's first quantum grade diamonds used used in many of the most exciting breakthroughs in quantum technology.

www.e6.com

Quantum Diamond Technologies Inc.

Quantum Diamond Technologies Incorporated (QDTI), a privately held company based in Somerville, Massachusetts, USA, was started to exploit quantum systems intelligently engineered into the diamond crystal – called nitrogen vacancy (NV) centers – based on world-leading research at Harvard University. QDTI is using the NV technology to build a quantum sensor capability with the potential to disrupt the biomedical detection and medical diagnostics fields. They are developing simple-to-use, rapid and highly sensitive diagnostics for the biomedical research, central lab and point-of-care markets.

www.qdti.com

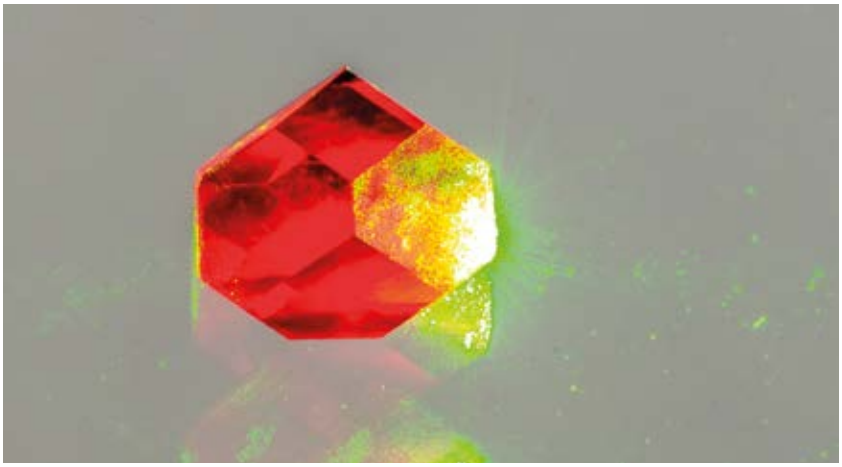


Fig. 3 Element Six DNV™ B1: green light shining through diamond nitrogen vacancies to enable room-temperature readout

light, using a compact, room-temperature device. This imaging technology enables QDTI to directly pinpoint magnetic tags corresponding to individual protein molecules.

What is a nitrogen vacancy center?

A series of pioneering studies in the 2000's demonstrated that the electronic spin associated with a nitrogen vacancy center can be manipulated and read out at room temperature using simple optical techniques. Synthetic diamond, manufactured by the chemical vapor deposition (CVD) method, allows for these quantum defects to be introduced into the material with a high degree of precision and performance.

NV centers are created by removing two adjacent carbon atoms from the diamond crystal structure and replacing one of them with a nitrogen atom, leaving a gap or vacancy next to it. The NV has an electronic spin that is highly sensitive to magnetic fields, forming the basis for sensitive magnetometry. The electronic spin can be detected and aligned simply by shining a green light onto the NV center and measuring the intensity of red light emitted, making the platform incredibly powerful.

Key to the exploitation of the NV color center in diamond for quantum technology applications is the process of optically-detected magnetic resonance. In this process, a light source – typically a green laser – is directed into a diamond containing NV centers. The green light excites fluorescence emission, and also polarizes the electronic spins associated with the NV centers due to their unique energy level structure. The properties of the surrounding diamond lattice give the NV electronic spins a long lifetime before they are randomized, compared to spins in other materials, because thermal vibrations of the diamond lattice interact with them only very weakly. This means we can construct diamond quantum devices with NV centers even at room temperature.

Microwaves can be used to probe the NV centers. The spin associated with each NV center absorbs microwaves at a frequency determined by the local magnetic field. When the microwaves are absorbed, the NV center is temporarily driven into an optical dark state, reducing its fluorescence emission. By measuring fluorescence from a large collection of NV centers while sweeping the microwave frequency, megapixel images of microscopic magnetic field patterns can be rapidly acquired over the entire diamond surface.

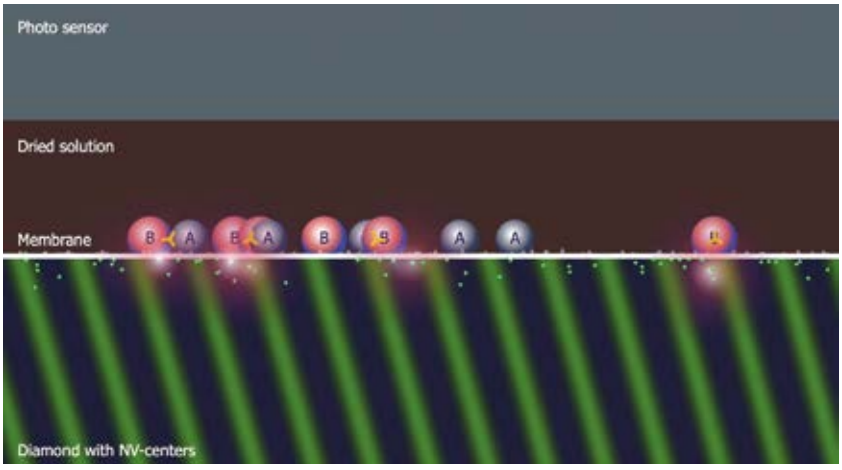


Fig. 4 Imaging platform: NV centers provide a magnetic field map image

The future: point-of-care diagnosis

QDTI's ultimate focus is on patient diagnosis at the point of care. Because diamond NV magnetometry can be conducted at room temperature, QDTI is confident that, with Element Six's support, it can produce a smaller and more compact cartridge-based device. This new solution will not require an experienced professional to operate it and is set to open up a range of possibilities for clinical and even at-home testing. The first prototypes of this device are expected to be ready for testing by 2023.

The next generation of DNV magnetometry tests may even be able to identify marker proteins for neurological conditions, inflammation and concussion. Another avenue of development is the detection of nucleic acid markers for cancer and infectious diseases.

"We are in awe of QDTI's ability to tackle incredibly complex and important problems and to find a solution each time. To see their units already being used in real benchmark tests is a testament to how much they have achieved in a short amount of time."

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A high-precision length measuring technique for laboratory and industry

Multibeam interferometers measure dynamic parameters simultaneously and with nanometer precision over a length of up to 80 m

Source all images: SIOS Meßtechnik

In the medical technology, semiconductor, and optics industries, as well as for calibration tasks, the highest accuracy is always required. Laser interferometers measure displacements with an accuracy up to 0.1 ppm and connect the macro world with the nano world through the unique property of measuring large ranges with enormous resolutions.

High-precision measuring systems are nowadays essential in science as well as in many industrial fields. However, as diverse as the areas of application are, their requirements are equally varied – for example in terms of easy handling, measurement uncertainty or applications in an industrial environment. As a company that has been equipping research facilities and calibration laboratories on the domestic market and around the world for around thirty years, SIOS Meßtechnik also delivers highly reliable performance in industrial applications with its new generation of multibeam interferometers. These devices are able to synchronously detect several degrees of freedom of a movement and can be adjusted very easily and precisely thanks to an integrated optical alignment function. SIOS also optimizes and modifies interferometric systems according to individual customer requirements.

"While scientific laboratories and national metrology institutes expect

▲SIOS' single and multibeam interferometers are able to synchronously detect several degrees of freedom of a movement and can be adjusted very easily and precisely thanks to an integrated optical alignment function. In addition, they are designed specifically to meet the needs of the respective applications and are suitable for a wide range of industrial applications due to their compactness and robustness.

The basic concept of all sensor versions is represented shown by the compact single-beam interferometer of the SP-NG product family, whose sensor head, including the adjustment joint, is only 133 × 91 × 54 mm – or 227 × 91 × 67 mm for long distance measurements

the highest accuracy, numerous users in high-tech industries appreciate that on the one hand the measuring systems can be used in a variety of situations, but also withstand harsh industrial operating conditions on the other," says Dr Denis Dontsov, managing director of SIOS Meßtechnik. "That's why we develop our laser interferometers specifically to be used in various different industrial sectors, and without losing any precision." SIOS interferometers are characterized by the fact that, depending on the model and thanks to their high precision of 0.1 ppm and a resolution of between 5 and 20 pm over a length of up to eighty meters, they can measure dynamic processes very quickly and simultaneously, for example, to calibrate coordinate measuring machines. Due to the simultaneous and highly synchronized measurement value acquisition, there is no falsification of the results, even at a high object speed of up to 3 m/s. Optical adjustment aids are also integrated into the measuring systems so that the correct alignment of the measuring setup can be done quickly, accurate and easily with the help of a graphical user interface. In this way, alignment-related measuring errors can be minimized, even over very short measurement ranges.

The light sources, frequency stabilized He-Ne lasers, are always placed outside the sensor at an uncritical distance to ensure that these high-precision measurements are not adversely affected by heat input. Since the laser beam reaches the sensor head through an optical fiber, there are only optical components in the sensor head that define its functionality that do not transfer any heat. All sensors and cables are completely closed and encapsulated. This means that even potentially dirtier operating environmental conditions cannot damage the robust interferometers of this new generation.

The matching multibeam interferometer for every application

SIOS' single and multibeam interferometers address a wide range of application scenarios – from calibration tasks and simultaneous displacement angle measurements to highly stable differential measurements and vibration analyses to multiaxis system combinations in which three-dimensional processes are recorded. The basic concept of all sensor versions is shown in the compact single-beam interferometer of the SP-NG product family whose sensor head, including the adjustment joint, is only 133 × 91 × 54 mm – or 227 × 91 × 67 mm for long distance measurements. This is because it is a precision length measuring system in which the single measuring beam is reflected by a tiny reflector along the same path, i.e. into itself. Thanks to this proven principle, there is a defined probing point on the target, so that alignment errors and the typical Abbe error can be compensated. The optical properties of those reflectors allow the detection and correction of such misalignments. As they are able to tilt up to ±12.5° without losing the measuring beam, quick and easy adjustment of the measuring set-ups are always possible. In terms of large measuring ranges or extensive calibration tasks, wireless temperature sensors or the modular SIOS LCS precision climate measuring station can also be used instead of the standard wired temperature sensors to record all environmental data in an uncomplicated and effective way.

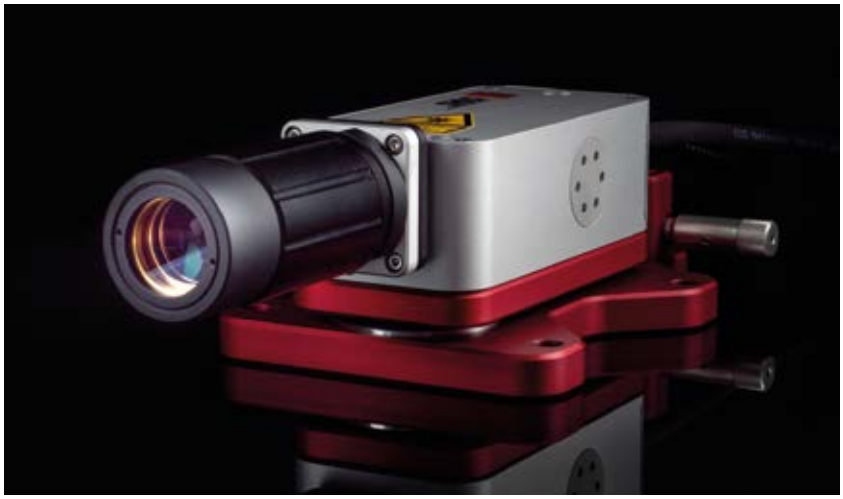
"Based on this concept, the three-beam models of the SP-TR series combine three single-beam laser interferometers in one," explains Dr Dontsov. "In this way, high-precision simultaneous displacement and angle measurements

Company

SIOS Meßtechnik

The company, based in Ilmenau, Thuringia, was founded as a spin-off of the 'Institut für Processmess- und Sensortechnik' of the Technical University of Ilmenau in 1991 to develop and manufacture precision measuring instruments. From the very beginning, there was a close scientific and technical cooperation between SIOS and its mother institute, which formed the basis for the development and manufacture of innovative precision measurement technology products with a focus on laser interferometry.
Some fields of application are precision metrology, calibration, mechanical engineering for precise measurement or positioning, optics and the semiconductor industry, medical technology, nano-measurement technology and geosciences. SIOS Meßtechnik is active worldwide and currently represented by 25 partner agencies in 22 important industrial nations.

https://sios.de



For vibration measurements on surfaces of any roughness, the sensor head of the shown laserinterferometer is equipped with additional optics.

become very easy." This is because these devices, which are only a few centimeters larger than single beam sensor heads, use only one He-Ne laser with a long-term laser frequency stability of $2 \cdot 10^{-8}$ for the three measurement channels, so that three values can be synchronously measured over a length of up to five meters with nanometer accuracy. If the acquisition of the horizontal and vertical straightness is also required as well as the linear position and the simultaneous determination of the pitch and yaw angle, a calibration interferometer of the latest generation can be used, the SP-C5 series. The straightness mirror is attached directly to the sensor head in this four-beam interferometer so that here too only two components need to be aligned to each other: the sensor head and its reflector. The device is therefore perfectly designed for the special requirements of machine and equipment manufacturers who would otherwise have to carry out their calibrations with the help of several linear positioning axes. The accuracy of the entire system would then be affected by the interaction of the rotatory and translatory deviations. "To meet the demands of various industrial applications, our interferometers are each available in vacuum versions and in special versions for OEM applications, in addition to the standard version," adds Dr Dontsov.

Compatibility of the systems allows multidimensional measurements

Several identical or different single and multibeam interferometers manufactured by SIOS can be combined with each other if required, whereby it is possible to operate them with only one supply and evaluation unit. In this way, all measured values of several axes can be recorded absolute synchronously at the same time. On the one hand, the Thuringian-based interferometry specialist offers an extensive product range for a wide range of standard applications, but on the other hand, these only represent around sixty percent of the product portfolio. "Almost half of our portfolio consists of devices that have been adapted or even newly developed for the specific applications of our customers," concludes Dr Dontsov. "This is how we ensure that every customer gets exactly what they need."

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High accuracy precision micro-lens arrays

Precision glass molding offers maximum manufacturing reproducibility and design accuracy

Chhavi Jain

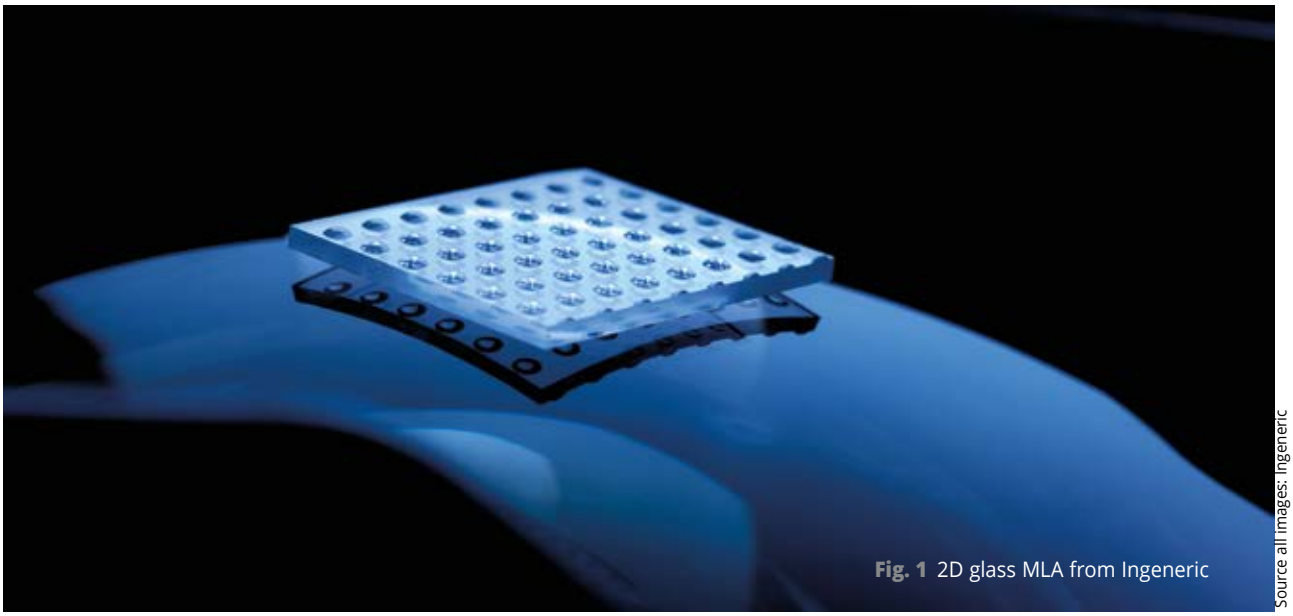

Fig. 1 2D glass MLA from Ingeneric

Source all images: Ingeneric

The demand for micro-optics with highest form accuracy and minimal design errors has shot up with rampant miniaturization of commercial optical systems. Strict design tolerances are further fueled by precision alignment procedures adopted in systems with limited space and short optical path lengths. When it comes to high optical and mechanical design accuracy and superior performance, precision glass molding offers one of the best solutions for the commercial production of micro-optical lenses and lens arrays. The high part-to-part manufacturing reproducibility and advanced in-house metrology solutions make sure that customer design requirements are met throughout the product lifetime.

Rapid miniaturization of optical systems and subassemblies is being witnessed in every industrial and commercial domain for improved device portability and the reduction of costs. These include digital communication systems, optical switching technologies, miniaturized imaging systems, sensing modules, augmented reality displays, miniature spectroscopy devices, medical endoscopy, and lidar.

A popular choice for light guidance in many micro-optical systems are optical fibers and fiber arrays, where they are often required to be coupled in free space to other active and passive micro-optical components such as light sources, photodetectors, integrated photonic waveguides, interconnects, beam steering, splitting and dispersive elements. Refractive micro-optical lenses and arrays are indispensable for light coupling when beam sizes are below a few millimeters and optical path lengths are of the order of millimeters. These lenses can have apertures that range anywhere from hundreds of microns to a few millimeters and have different lens shapes ranging from plano-convex, bi-convex to convex-concave apertures.

Choosing the right micro-fabrication technology

Miniaturization dictates that optical components are placed very close together in space, necessitating a highly precise alignment of subcomponents within the system to minimize device insertion loss. This miniaturization of optical systems and reduction in optical path lengths imposes tighter mechanical and optical tolerance limits for manufacturing.

Amongst different commercial microfabrication technologies, precision molding offers one of the most

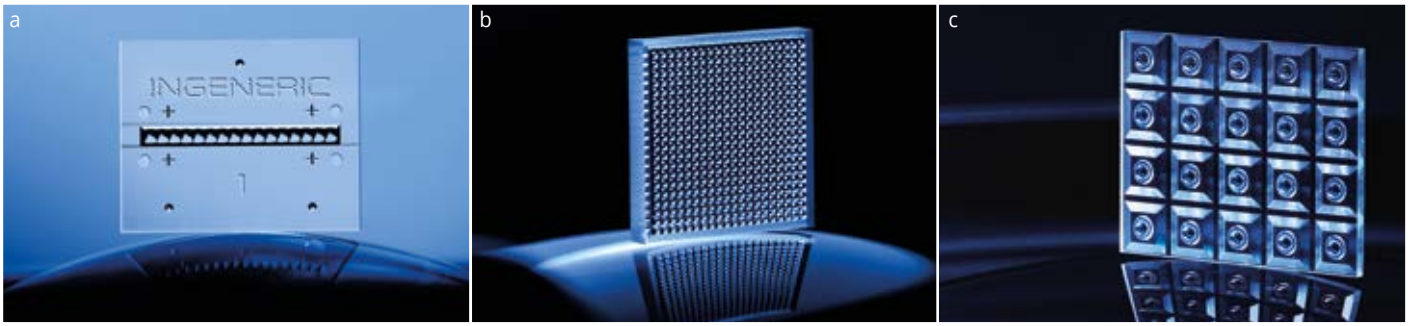

Fig. 2 1×16 plano-convex demonstrator MLA from Ingeneric (a); 2D large port count glass MLA from Ingeneric (b); 2D glass Ingeneric MLA for optical coupling applications (c)

suitable solutions for customers when extremely high design accuracy and homogeneity of part-to-part optics is required. With an expertise acquired over many years in toolmaking and precision glass molding, Ingeneric can not only fulfill the toughest manufacturing requirements but also continuously develops its in-house optical measurement solutions for the series testing and qualification of geometrical and optical features in the micro-domain.

To demonstrate the advantages of its technologies, Ingeneric has designed and developed 1D (1×16) and 2D (10×10) refractive glass MLAs as technology demonstrators with very small form deviations and pitch error. The measurement results of these lenses reflect the many advantages of precision molding, which are detailed further here.

Tight tolerance constraints on precision micro-optics

A noteworthy difference between bulk and micro-optical components apart from their dimension lies in the allowed tolerance range of their optical design. For example, to maintain low beam pointing errors in MLAs with pitch distances below a millimeter, a total array pitch error of only a few hundred nanometers is allowed. To achieve high transmission capacity and low device insertion loss for microlenses, a very high radius of curvature (ROC) and form accuracy (peak-to-valley, PV) and root mean square (RMS) irregularity and very low surface roughness are prescribed.

Highest manufacturing reproducibility for series MLAs

The key competence of Ingeneric's technology lies in a highly reproducible feature transfer process from a highly accurate master mold to glass arrays during precision molding. It is ensured that the highly precise master mold achieves sub-micron design accuracy during toolmaking. During the subsequent molding step, a complete replication of mold shape and features is made from the heated glass preforms, without the requirement for further machining. A 1:1 feature transfer process from the mold to the wafers ensures that only minimal deviations occur between wafers within a production batch (Fig. 3). Even for wafers from different production batches, only minimal form and pitch deviations are observed, proving molding to be an extremely stable process.

In addition to optical lens structures, the molds can be precisely inscribed with fiducial (alignment) marks such as circles, cross shaped marks, standoffs, and support structures that can be transferred to glass substrates during molding. These fiducials are extremely useful for the passive alignment of lens arrays using machine vision systems in an optical assembly.

The following list gives a quick glimpse into the advantages of precision glass molding:

- Significant cost savings through high mold reproducibility
- Low beam-pointing errors owing to negligible pitch errors
- High focal-length uniformity thanks to high radius uniformity

MLA parameter	tolerance range for precision molding (lens CA = 250 µm)
ROC deviation	<2 – 3%
pitch error (lens to lens)	<100 nm (pitch = 250 µm)
pitch error per array	<700 nm (up to 5 mm array lengths)
PV irregularity	<250 nm
RMS irregularity	<60 nm
surface roughness	<10 nm

Table 1 Realizing tight tolerance constraints on precision micro-optics

Company

INGENERIC

INGENERIC develops and manufactures optical components for high-power applications and optical systems for research, medicine, measurement, and diverse industrial applications. The company was founded in 2001 in Aachen, Germany and has about a hundred employees today. The year 2019 saw the fusion of INGENERIC with Aixtooling, a leading German producer of molding tools for precision optics.
INGENERIC offers worldwide competence in the complete production chain, from design of lenses and systems to the production of prototype and small series, up to mass production. The product portfolio includes fast und slow-axis collimation, collimation modules, beam transformation optics, microlens arrays, aspheres, acylindrical and free form optics. With its unique technology profile, INGENERIC has developed itself into a leading supplier of beam transformation optics for semiconductor lasers. The highly precise micro-optic lenses are being deployed in rapidly emerging markets such as medical technology (endoscopy) and optical data-communications.

www.ingeneric.com

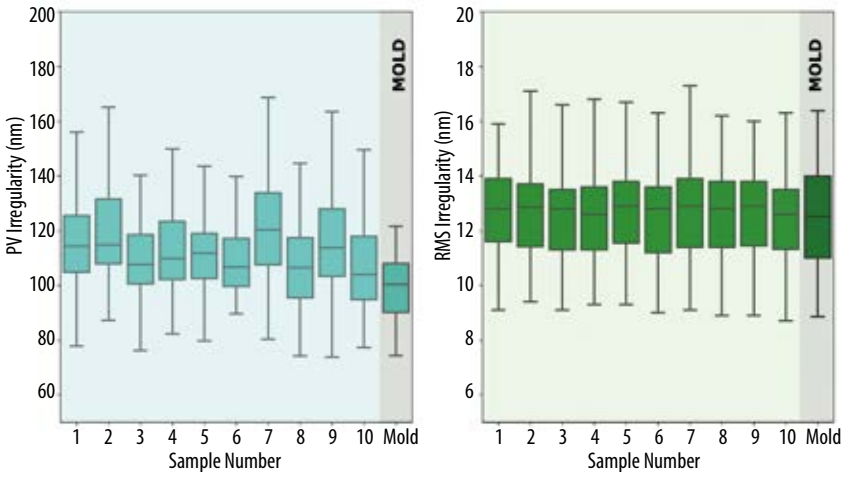

Fig. 3 Box plots showing a comparison of PV and RMS form irregularity between mold and different wafers in a production batch for a 10×10, 2D MLA made via precision molding

- Low optical losses due to minimal mold defects and low roughness
- Minimal crosstalk of signals from negligible dead zones in array

High accuracy replication of form and surface features

From measurements of different wafers from different batches, it is observed that even after repeated cycles of molding, the form of the mold is effectively and repeatably transferred to the wafers, without the incurrence of any additional or significant form errors. This low form error ensures low wave-front aberrations on lenses so that the highest transmission efficiency and high MTFs (modulation transfer function) for imaging applications are achieved. Engineering the optimum toolpath kinematics during the in-house toolmaking process ensures master molds with the highest surface finish, so that low areal roughness on the glass surface can be achieved. For example, optical areal surface roughness (S_q) <10 nm over the entire lens aperture (>200 µm) has been achieved for applications at infrared wavelengths.

Large array fill factors, smaller dead zones than photolithography

A principal advantage of the precision molding technology over commercial photolithography is its ability to produce larger lens optical aperture/pitch ratios ($CA_{optical}$/pitch) and subsequently larger fill factors of spherical and aspherical lenses in an array. Large fill factor arrays are especially advantageous when large numerical aperture lenses are required for fixed design constraints on array pitch and working distances to achieve large device packaging densities (e.g. laser diode to fiber coupling in small scale devices). Moreover, for applications in LED imaging or beam homogenizing, a small $CA_{optical}$/pitch ratio would result in the divergence of incoming rays being larger than the array acceptance angle, thereby decreasing the transmission intensity of light into the image plane. Large $CA_{optical}$/pitch ratios are also beneficial when dead zones (optically inactive areas between neighboring lenses) in an array need to be kept to a minimum.

Case Study 1: Large $CA_{optical}$/pitch ratios in precision molded MLAs

A statistical batch of Ingeneric's prototype plano-convex 1×16 MLAs were measured along with similar focal length, pitch and numerical aperture quartz MLAs manufactured via commercial photolithography. The form measurements of lenses as a function of changing aperture were used to compare their $CA_{optical}$/pitch ratios. Here we can define the lens optical clear aperture ($CA_{optical}$) according to ISO 14881-1 as the lens surface where the PV form irregularity is smaller than $\lambda/4$ where

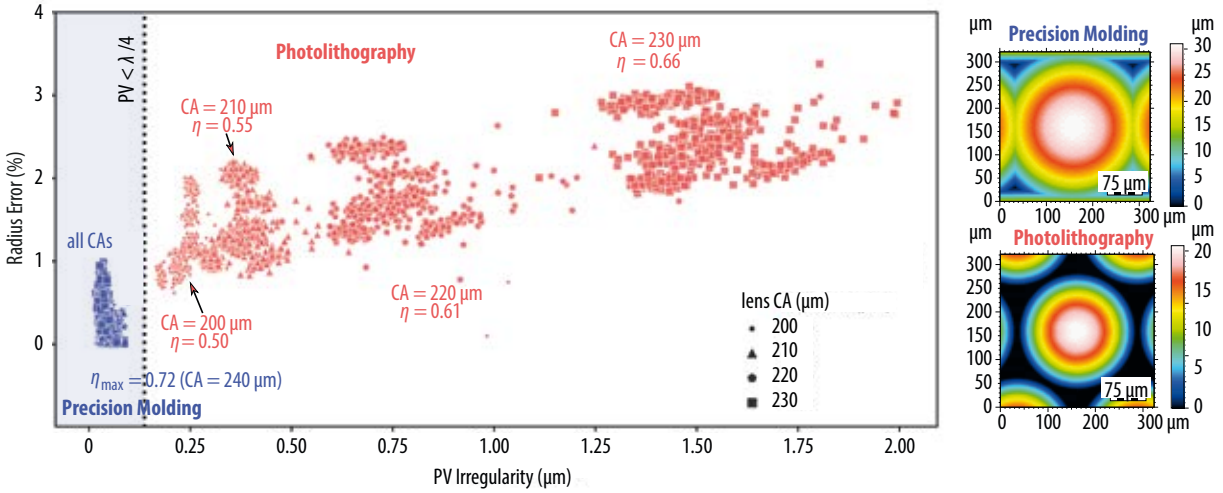

Fig. 4 Comparison of radius error % (*y* axis) and PV irregularity (*x* axis) for Ingeneric and lithographic quartz lens arrays as a function of the lens optical CA and fill factors (η). Both have same array pitch (250 µm), lens shape (spherical) and similar lens focal lengths (~0.7 mm). A refractive index difference of the glasses causes a different surface sag height for same focal lengths, as shown in surface topology profiles (right).

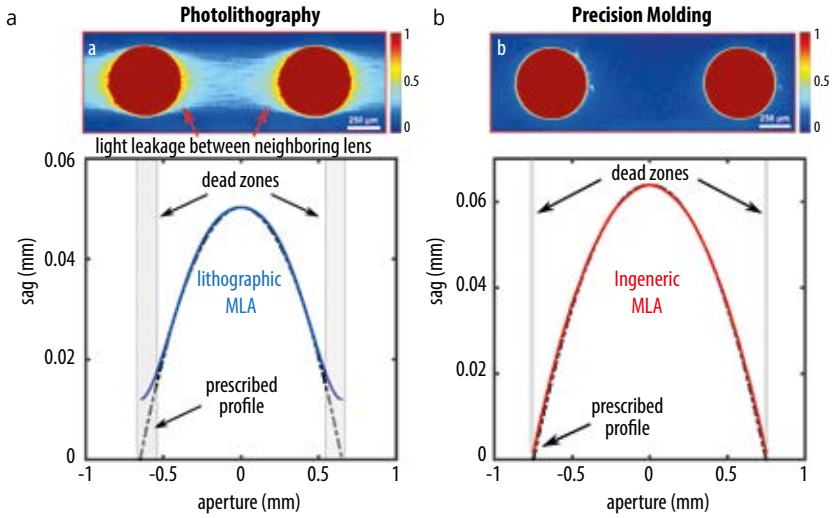

Fig. 5 Comparison of form filling and dead zones in a photolithographic lens (a) and an Ingeneric lens (b). Dead zones lead to increased MLA optical loss from light leakage between neighboring lenses.

λ is the form measurement wavelength (<137 nm for λ = 546 nm).

In Fig. 4 it is shown that for a fixed lens-to-lens pitch of 250 µm, Ingeneric MLAs can achieve fill factors of up to 0.72. For lithographic lenses, a strong dependence of the radius and form errors on increasing lens aperture is evident. The criteria of PV form errors <λ/4 can only be achieved for CA < 200 µm, which limits the achievable fill factors for lithographic 1D arrays to <0.5. Moreover, for these ratios, the corresponding dead zones in the lithographic array are >20 %, while for precision molding they are below 5 %.

Case Study 2: Negligible dead zones in aspherical MLAs for NASA

The presence of smaller dead zones in Ingenerics 1×16 aspherical MLAs has also been reinforced by optical benchtop experiments by Nasa. As part of the Pace mission, Nasa is planning to measure the 'color of the oceans' with unprecedented spectral resolution from a satellite scheduled to launch in 2023.

The satellite will have a 1×16 aspherical microlens array from Ingeneric that couples the received short-wave infrared signals with high efficiency into a 1×16 bundle of a multimode fiber array attached to a spectrograph on the telescope.

Commercial lithographic MLAs were initially tested by Nasa. During optical experiments, considerable light leakage from dead zones between the lithographic MLA was observed. To reduce optical losses, Nasa turned to precision molded MLAs from Ingeneric (with slightly larger pitch and aperture). Geometrical form measurements of lens arrays showed dead zones in lithographic MLAs to be almost an order of magnitude higher than the Ingeneric MLAs (Fig. 5). Therefore, by ensuring complete form filling over the complete lens aperture, precision molding can significantly reduce dead zones and prevent signal crosstalk and optical loss.

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Info-Box

Technology demonstrator for microlens arrays (MLAs) facilitates testing in customer specific optical systems.

Precision molding for commercial production of glass MLAs is new for users who have long relied on photolithographic MLAs.

To give R&D specialists a chance to test precision molded MLAs in their optical systems, Ingeneric has developed 1D and 2D MLAs that can be requested over the company website. The 1D array is a plano-convex 1×16 MLA that allows the coupling of light signals into a fiber array or collimation of their output either in free space or with an intermediate glass spacer. Similarly, the 2D 10×10 glass MLA with a high pitch accuracy has been developed for coupling applications with 2D fiber arrays. Dr Stefan Hambuecker, managing partner at Ingeneric, explains how the demonstrators can reach out to a wide customer base: "While we develop many of our projects closely with customers – with the corresponding confidentiality clauses in place – we are introducing the MLA demonstrator for the first time, a microlens array that developers can easily integrate into their optical systems for testing."

For those interested in extensive technical data and the results from detailed measurements on the MLA demonstrator, the company whitepaper "Perfecting the art of fiber collimation with microlens arrays" can be requested at fiber-collimator-array.ingeneric.com, or by getting in touch with Ingeneric specialists.

Author

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Augmented / virtual / mixed reality systems optical terminology

Definitions, explanation, considerations for requirements formation – part I: field of view, pixel resolution, and CTF / MTF

Olga Resnik, Yosi Arazi, Yoni Kaganovitz, and Assaf Levy-Beeri

Source all images: Joya Team

Fig. 1 Olga is using augmented reality glasses to play with her virtual pet

The AR / VR / MR systems field has recently expanded to many different applications and markets, and created a need for a common language to clear the misunderstanding and misinterpretation of terminology and to ensure efficient communication. We want to share our experience of more than two decades with the professional community and create a standard for everyone, starting from entrepreneurs with use case and application ideas, system engineers that define the system architecture and requirements, optical designers and engineers that develop these systems, assembly and testing engineers, and technicians.

The incentive for this two-part paper originates in the lack of common terminology in the vastly expanding AR (augmented reality) / VR (virtual reality) / MR (mixed reality) systems span. We can generally call them XR systems (referring to XR for extended reality system) and their adoption in many different fields of application. Many people and companies from early-stage start-ups to large corporations entered this market recently, which is growing day by day. Enormous numbers of patents are written and granted, new applications are continuously being created, but the fundamental terminology in this field is not well-defined. This may originate from the fact that this technology was owned by just a very few companies in the world, and strictly confined to the niche military market. The professional information regarding these systems, including the formation of parameter definitions and requirements as well as the system architecture, design guidelines and concepts, were treated as a company's competitive intellectual property and kept strictly confidential. We happened to be in one of the greatest schools of XR Systems, being part of the system engineering and optical design of HMD systems (helmet-mounted display systems). This field is now much more open, more and more information is published and we also want to share the experience of more than two decades with the growing professional community.

Dealing with an XR system starts with understanding and covering a list of aspects or parameters that need consideration. These parameters are derived from specific use cases or user stories and have to support the intended functionality. We categorize

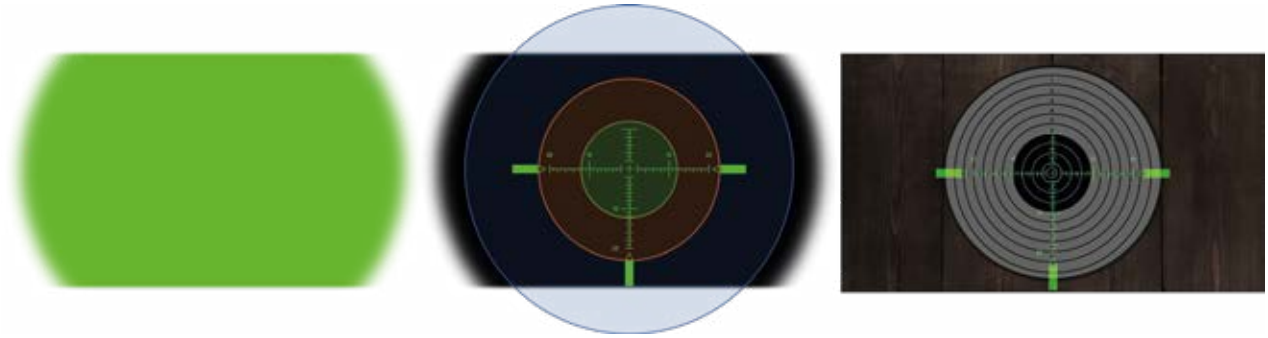

Fig. 2 Field of view shape and zones illustration: left image shows the system FOV shape with a full green image projected. The center image shows the system FOV with a real projected image and the different FOV zones – primary FOV zone (inner circle), secondary FOV zone (middle circle) and peripheral FOV zone (outer circle) where the FOV zones are used to define different sets of system performance requirements. The right image shows the real projected image with a see-through real world background, illustrating that projected image edges are not seen on the background.

these parameters into two main groups: imaging parameters and non-imaging parameters. This categorization helps to classify the parameters by the different optical software tools and engineering specialties needed during the design of the overall system. Imaging parameters are output from the design process with the use of imaging software tools such as CodeV from Synopsis, or the more commonly used Zemax sequential module (OpticStudio), OSLO etc.; non-imaging parameters are output from the design process with the use of non-imaging software tools such as LightTools from Synopsis, or Zemax non-sequential module, TracePro etc. There are also parameters that do not fall into either of the two categories, such as Eye Relief, IPD, System Pupil/Eye Motion Box or others that are system requirements or mechanical constraints.

Imaging parameters of XR systems include:

- field of view (FOV)
- pixel resolution
- CTF / MTF
- apparent image distance (AID)
- field curvature
- distortion
- see-through power
- symbol position accuracy
- prismatic deviation

Non-imaging parameters of XR systems include:

- spectrum and polarization
- ghost and stray light
- uniformity
- see-through contrast
- see-through FOV / obscuration
- see-through transmission and uniformity

We will discuss the first three terms of each list. More information about these and additional terms can be found in [1].

Field of view

FOV specifies the angular size of the image projected to the user's eye. FOV is defined in degrees [°], usually specifying a system's horizontal and vertical FOV; sometimes diagonal FOV is also specified. In systems with a finite apparent image distance, the FOV may be specified as the actual size in millimeters [mm], stating the image distance, usually in meters [m].

In most displays and camera systems including XR systems, the natural FOV shape is neither round nor rectangular, but a combination of both. The reason for this is the nature of the system's building blocks. In general, optical systems are built from optics, i.e. a relay lens and an image source such as a display (or sensor in case of camera). The display has, of course, a rectangular shape; lens shape is basically round because of the manufacturing processes. Lenses can be cut to have any shape, but still the fundamental issue is that the image quality reduces with FOV due to aberrations. So when designing a system with a rectangular FOV so that the whole display is fully used, this means that the optics will be more complicated, heavy and expensive, but the gain in a larger FOV will only be at the displayed image diagonal corners, which are in most cases not important. Due to this, the FOV shape in AR systems is often a truncated circular shape with gradually fading edges, as shown in (Fig. 2 left). This shape is not seen by the user if the image content is created in such a way as to conceal the actual outline. The case is different in VR systems or when displaying a full video image.

A FOV specification shall include the following details:

A FOV requirement shall include tolerances. In addition, a sketch shall be provided to see the FOV shape.

FOV is not only a performances parameter, but also a definition for other performance parameters such as resolution, CTF (or MTF), field curvature and others, so we define FOV zones to specify the requirements for other performance parameters within these different FOV zones (Fig. 2 center).

The FOV requirement values depend on the system's intended use. The projected image type and characteristics have a significant impact on the FOV requirements. Here are several different cases when the system FOV requirement should be tailored to the use-case scenarios in order to create an optimal design.

In the case of an AR system when the projected image is combined with a direct scene view, a wider FOV does not have high added value in most applications. The FOV can be shifted from center viewing to the side or diagonal (this is often called a glance display) or up/down, depending on the specific application and the optimal position of the displayed information.

Company

JOYA Team

JOYA Team is an optical technologies house offering optical system development services. Our goal is to help our customers and partners to design an exclusive, tailor-made optical system. JOYA Team is a multidisciplinary team with more than twenty years of joint experience specializing in optical system design and engineering for AR/VR and night vision systems. We have vast experience in illumination and display applications. We also have hands-on experience in medical devices and automotive industry applications.

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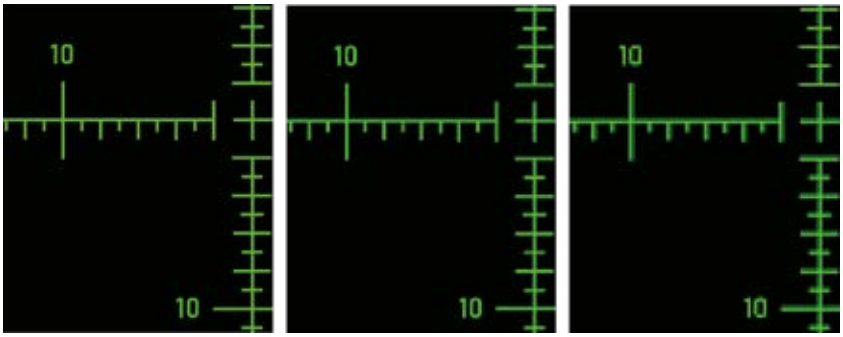

Fig. 3 Illustration of microdisplay resolution impact on image pixel resolution. The same image is projected on microdisplays with different resolutions: left image – 1920 × 1080 (FHD) resolution; center image – 1024 × 576 (WSVGA) or 1024 × 768 (XGA) resolution; right image – 640 × 480 (VGA) resolution. The symbol line width should be at least three pixels for proper visual perception, which is the case for the left image. In order to maintain the visibility of text and symbols in a lower resolution image, the font and symbol size have to be increased, thus increasing pixel resolution.

In the case of an MR system when the projected image is combined with a direct viewing camera/night vision system, the projected FOV shall match the direct viewing channel and extending the FOV further does not bring any added value.

In the case of a VR system when the projected image must create a sense of immersion, a wide system FOV is required, but the image resolution in the peripheral FOV can be dramatically reduced.

Pixel resolution

Since the image source is a key component of the XR system and its impact on the resulting system performance is very significant, we put the emphasis on the integration of the microdisplay as part of the system design at the very beginning of the design, and this should be done in close correlation to the optical design. This is crucial for overall design optimization and the specifications shall be in accordance.

Microdisplays are usually used as the image source in XR systems because of the incentive to minimize the system size/volume/weight/cost etc. The microdisplay size and resolution is usually specified by its diagonal size and resolution abbreviation, for example a 0.62" SXGA display. The image source size and resolution determine the smallest possible detail that can be projected onto the user's eye. This is related to the term 'pixel resolution', which is illustrated in Fig. 3.

Pixel resolution is defined in [mrad/pixel] – this is simply given by the angular size of the smallest image detail (when the image is projected to infinity). The overall system quality (CTF) will determine whether this resolution will be resolvable by the user, but the image source resolution limits the highest resolution that can be displayed. This term is also known as the Nyquist frequency, which is specified in [cycles/mrad] or [lp/mrad].

Image source specifications shall include the following details:

Image source size shall be specified in [mm], in both horizontal and vertical axes. This adds the information about the image aspect ratio that can be significant for adjusting the projected image format. For a micro-display image source, the pixel size shall be specified in [mm], with detailed sub-pixel structure and arrangement information, preferably with an illustration similar to Fig. 4.

The pixel resolution shall be specified in [mrad/pixel].

The image source requirements strongly depend on the system's intended use, and the projected image type and characteristics have a significant impact on the specific requirements. Here are several different cases when system image source requirements should be tailored to the use case scenarios in order to create an optimal design.

In the case of an AR system when the projected image contains symbols or text that are combined with a direct scene view and an accurate symbol position on real world details is necessary, a higher image resolution brings the required added value.

In the case of an MR system when the projected image is combined with a direct viewing camera/night vision system, the projected image resolution shall match the direct viewing image resolution so that there is no resonance that can cause any uncomfortable effects.

In the case of a VR system when a full video image is projected, a high primary FOV resolution creates a crispy and sharp image (provided the system CTF is sufficient), but the peripheral FOV resolution can be dramatically reduced since the human eye resolution is high only in a very narrow central FOV.

RGB 3 rectangular subpixel structure forming a square pixel

RGGB 4 square subpixel structure

RGB 3 hexagonal subpixel structure

Fig. 4 Different types of microdisplay sub-pixel structure and arrangement. The different arrangements are related to the image Nyquist frequency resolution, which may differ for horizontal and vertical axes

CTF / MTF

MTF is a commonly used term for the image quality measure in optical systems, but this term is often not fully understood. The MTF (modulation transfer function) is a measure of an element or system that describes the system response to a sine image input. This parameter describes what the corresponding system output would be if a sine wave intensity profile is the input. The MTF is given in [%]. Without giving this another thought, the optical design goal is to reach an MTF close to the diffraction limit, namely asking for the best physically possible design without any aberrations.

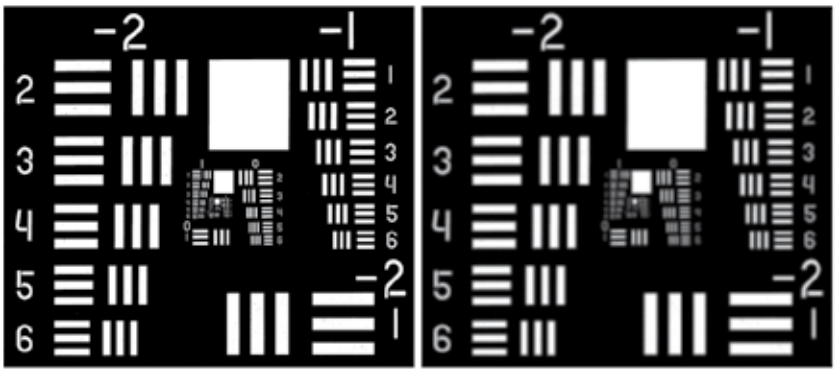

Fig. 5 The difference between a high CTF system image and the low CTF image for the same projected image quality. This illustrates the difference between the nominal diffraction limit requirement: left image showing resolution targets with a resolution limit of group 1 – 6; and the real as-built system image: right image showing resolution targets with a resolution limit in group 0 – 6.

The MTF term is historically used mainly because it was more convenient to calculate using formulas. MTF was the relevant term for systems using CRT displays but, when considering XR display systems or camera systems, this term can be replaced by a more appropriate and easy-to-understand term – CTF (contrast transfer function).

In XR systems, the image source is a pixelated display, so considering a sine intensity profile is neither very realistic nor helpful. The display image has a discrete square wave intensity profile nature, so a CTF parameter representing the system response to a square wave intensity profile of a certain frequency should be used. The highest system frequency – the Nyquist frequency, is when the square wave is produced by creating a one pixel 'on' and one pixel 'off' sequence. The system CTF then describes what the system output would be relative to this input, or what the resulting image contrast between the 'on' pixels and the 'off' pixels would be, which is also given in [%]. Considering this contrast as a measure of the system image quality, it is easy to connect the CTF numbers with the projected image quality that will be seen and perceived by the user.

The CTF / MTF specifications shall include the following details:

Generally for XR systems we propose to define the CTF as a more adequate measure of image quality for a pixelated image source.

The system CTF, considering image source contrast, electronics and other system components, shall be defined on a system level. The image source (microdisplay) contrast is often not considered at all, while some microdisplay technologies have a CTF well below 100 % and may then have a significant impact on the system CTF.

The optical system (relay lens) CTF shall be derived and defined separately. A separate CTF for the optics standalone is a 'must' requirement for the optical imaging design. Although the CTF is the parameter used for the design and the final system testing, many lens manufacturers still provide only MTF measurements due to their equipment capabilities, so both terms are often used.

The CTF shall be defined for a specific spatial frequency, for Nyquist frequency and/or for 1/*N* Nyquist frequency, where *N* is a number of pixels creating a typical line width for specific use cases.

The CTF shall be defined for a given measurement pupil size, which correlates to the user's eye pupil size and depends on outside lighting conditions. CTF requirements can also be defined for a different spectrum, different pupil positions within the system pupil, and different exit pupil distances within the system eye motion box.

The CTF requirements shall be defined separately for different FOV zones, where applicable. The requirements shall be defined for both the vertical and horizontal periodic line patterns (tangential and sagittal), for a real as-built optical system rather than just for nominal system design (Fig. 5).

Fig. 6 Illustration of CTF impact on projected image quality: the left image shows the original projected video image; the right image shows the resulting image as viewed by the user. The fine detail resolution is poorer and less crisp, creating a poorer user experience. (Image courtesy of Synopsys)

The CTF is the main optical system image quality measure and the CTF requirements strongly depend on the system's intended use. On the other hand, overkill CTF requirements have a high impact on optical system complexity, size, weight and cost. The more detailed and accurate the CTF requirements are, considering the actual intended use of the system and the projected image characteristics, the better optimization can be done in the optical design to minimize the high quality 'cost'. Here are several different cases when system CTF requirements should be tailored to the use-case scenarios in order to create an optimal design.

In all XR system types, it is very important to consider the human vision characteristics to produce the requirements that are just right for the mission or the use case. A significantly higher CTF will just slightly improve the user experience of image quality and sharpness but is in many cases not justified and results in the optical system not being optimal.

The distinction of CTF requirements for different FOV zones – primary / secondary / peripheral FOV areas – is one of the tools for system customization to human vision. In addition, in systems with differentiated resolution for different FOV areas, the CTF requirements shall match the different resolution settings.

In the case of an AR system when the projected image contains symbols or text, the line width of these elements is typically several pixels, and the CTF requirements for the Nyquist frequency image resolution do not bring high added value and are an overkill requirement.

The image quality and sharpness perception of a symbolic or a text image is different from that of a full video image. So in the case of a VR system when a full video image is projected, the image quality of a Nyquist frequency is very important. The CTF at the Nyquist frequency determines the projected image crispness and resolution of small details (see Fig. 6).

In the case of an MR system when the projected synthetic image is combined with a direct viewing camera/night vision image, the two images' CTF shall be close so that there is no resonance that can be perceived by the user as a combination of a sharper and a more blurred image. In addition, one should keep in mind that when the direct viewing image is projected onto the user's eye by the projection system optics, the resulting CTF will be the multiplication of the direct viewing system CTF with the projection system CTF.

Conclusion part I

In this part we attempted to explain several most important imaging parameters that form the base requirements list for an XR System specification. We tried to give a perspective of different factors to consider when specifying these requirements for different system types, based on our knowledge and experience. In general, each requirement formation strongly depends on the specific use case in question and the design considerations have to focus on the use case in order to provide the highest value to the user and to create an optimal working point and trade-off between the different parameters. This is a key to the final product success, since based on these requirements the actual system design work is done. The final product is a reflection of the requirements formation process, which is actually like planting the seeds of the system you are intending to create and build.

In the next part we will cover several most important non-imaging parameters that form the complementary part of the base requirements list for an XR system specification. This part of system specification is often treated with less attention, and in many cases is the reason for dissatisfactory system performances.

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[1] Optical Terms Library, joyateam.com/blog/categories/optical-terms-library
[2] Microdisplay Technologies, AR, and HUDs, oled-info.com/microdisplay-technologies-ar-and-huds

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Wetzlar, Germany

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"It was a festival!"

Review: Blechexpo and Schweisstec 2021, 26 – 29 October, Stuttgart, Germany

Source: P.E. Schall

In a great atmosphere and with a world-class supplementary programme, the industry sector celebrated the personal exchange of information on cutting-edge technologies for standalone and system solutions for the fabrication of parts made from sheet metal, profiles and pipe.

Along with the 8th Schweisstec international trade fair for joining technology, the 15th Blechexpo international trade fair for sheet metal working was also highly successful. "Full exhibition halls, a great mood, satisfied exhibitors. There's no substitute for an on-site trade fair," concludes Georg Knauer concisely, project manager of the trade fair duo. 953 exhibitors from Germany, Italy, Austria, Turkey, Switzerland and the Benelux countries showcased top sheet metal processing and metalworking technology on 108,000 square metres of exhibition floor space in nine halls. All the industry's big names were on hand at this trade fair highlight in Stuttgart.

Bettina Schall, managing director of trade fair promoters P. E. Schall, extends her thanks to all trade visitors and exhibitors for their active participation. "Although the event wasn't affected by a compulsory interruption, due to the fact that it's held once every two years, we all had to accept certain restrictions in the light of the current situation. All of you contributed to ensuring that the stipulated conditions were adhered to, and that a personal exchange of information was possible at the on-site trade fair. For this I thank all of you, as well as the organizers of supplementary events including Blechexpo Award and Blechexpo Steel Convent."

Numerous exhibitors confirmed that the high-quality visitors had expressed strong and concrete interest in the products and services on show. Everyone had eagerly awaited this live trade fair in autumn 2021, and were hungry for information about their particular aspect of sheet metal processing.Traditionally, exhibitors and expert visitors profit from the strictly practice-oriented trade fair concept and the synergy effects of the trade fair duo.

Along with the 9th Schweisstec international trade fair for joining technology, the 16th Blechexpo international trade fair for sheet metal working will take place in Stuttgart from the 7th to the 10th of October, 2023.

www.blechexpo-messe.de
www.schweisstec-messe.de

"Exceeded expectations by far"

Review: Medica and Compamed, 15 – 18 November 2021, Duesseldorf, Germany

Visitors and exhibitors were in good spirits throughout – personal encounters once again took centre stage. After their four-day run as an in-person event, Medica and Compamed have achieved extremely successful results. The world's leading information and communication platforms for the medical technology industry and its supplier sector presented a wealth of important innovations as well as an accompanying programme

Source: Messe Düsseldorf

that covered a wide range of topics (supplemented by online content) and did justice to their internationally prestigious position. "The atmosphere in the trade fair halls was relaxed and characterized by a sense of optimism throughout; conversations with our customers have shown that in many cases, we have exceeded expectations. People were finally able to establish new contacts and intensify existing ons in person," said Erhard Wienkamp, managing director of Messe Düsseldorf, visibly pleased as he took stock of the past few days.

46,000 visitors from 150 countries seized the opportunity to engage in person with the 3,033 Medica and 490 Compamed exhibitors in Düsseldorf. They obtained information on the comprehensive range of innovations for outpatient and inpatient care, including every step of their development and manufacture, and tried out many innovative products live in the trade fair halls.

"The numbers are encouraging, and back in spring were hardly expected to be at this level. The exhibitors are happy to have come to Düsseldorf and are already actively inquiring about options to take part next year," says Christian Grosser, director health and medical technologies at Messe Düsseldorf.

The industry portals medica.de and compamed.de added a range of offers in line with the live events at the trade fairs. This allowed users to access live streams to watch the forum presentations running parallel to the trade fairs as well as the 44th German Hospital Conference and the Medica Medicine and Sports Conference. They could network via the special matchmaking tool, and obtain information on innovative products in the exhibitors' online showrooms.

With its joint stand, the IVAM Microtechnology Network was once again one of the largest exhibitors at Compamed. 42 companies and institutes from nine countries were represented at this fair alone, presenting a range of innovations that included various microcomponents, solutions for smart textiles and coatings as well as manufacturing and processing methods.

Compamed and Medica will be back 14 – 17 November 2022 in Duesseldorf.

www.medica-tradefair.com
www.compamed-tradefair.com

"A successful return as an in-person event"

Review: Formnext, 16 – 19 November 2021, Frankfurt, Germany

Now in its seventh year, Formnext 2021 once again gave a warm welcome to the international AM community and, following last year's online-only event, built on the remarkable successes of previous years. The exhibition featured a series of world premieres throughout the entire process chain, demonstrating the ever-expanding fields of application for additive manufacturing and its impressive potential for the future. Exhibitors and attendees also offered solutions to urgent and important future issues, such as decentralized production, secure process chains, efficiency, and sustainability.

Over the four days, the event once again turned Frankfurt into an international center of innovation for global additive manufacturing and modern industrial production. Formnext 2021 saw impressive exhibitor numbers, with more than 600 exhibitors from 36 countries. 17,859 specialists and executives from 76 nations had the opportunity to experience Formnext over three levels of the exhibition halls 11 and 12 of the Frankfurt exhibition grounds, covering a total floor space of 30,000 square meters.

The exhibitors and extensive supporting program of events demonstrated the broad capability of industrial 3D printing for numerous user industries. Visitors were able to discover innovative solutions that they could use to make their own production more efficient and sustainable. Above all, attendees clearly relished the opportunity to finally meet one another and interact in person once again. The event was held under the highest '2G' safety conditions, meaning that only those fully vaccinated against or recovered from Covid-19 were allowed to attend.

Companies such as 3D Systems, Additive Industries, Addup, Arburg, BigRep, Carbon, Cubicure, Desktop Metal, DMG Mori, Dyemansion, EOS, Evonik, ExOne, Farsoon, Formlabs, Fraunhofer Gesellschaft, GE Additive, HP, Incus, Keyence, Markforged, Materialise, Nexa3D, Renishaw, Ricoh, Siemens, Sigma Labs, Sisma, Stratasys, Trumpf, Voxeljet, XJet and many more demonstrated their innovative additive technologies, showcasing advanced solutions for the future of industrial manufacturing. Established companies such as BASF, Covestro, Hexagon, Höganäs, Sandvik, as well as a large number of innovative start-ups presented a series of world premieres throughout the entire process chain; from manufacturing technologies through to materials, software, and post-processing solutions.

Source: Mesago, M. Kutt

Successful launch of the ASTM Standards Forum

On the day prior to Formnext more than 120 participants attended the premiere of the ASTM Standards Forum, supported by the USCS, ISO and Formnext. This successful launch underlines the importance of transatlantic efforts to create joint standards. The Standards Forum will be back in 2022.

Formnext Digital Days on 30 November and 1 December 2021 offered the opportunity to discover the innovations and future developments online for those who were unable to attend the fair due to travel restrictions or the current situation.

The next Formnext will take place in Frankfurt am Main, Germany, from 15 – 18 November 2022.

https://formnext.mesago.com

Preview: W3+ Fair 2022

16 & 17 March 2022, Wetzlar, Germany

Optics, photonics, electronics and mechanics are key technologies that drive numerous innovations that make the world a bit safer, healthier, more comfortable and sustainable. Since 2014, these industry sectors have been meeting in the optics hub of Wetzlar, in order to initiate and develop new ideas together. In March 2022, W3+ Fair will again be hosted as a live event at Buderus Arena Wetzlar (renamed from Rittal Arena on 1 January 2022), this time flanked with the new fringe conference, N-Tec Talks. Alongside numerous exhibitors, the professional audience can look forward to a highly varied range of events.

After last year's interruption due to the corona pandemic, attendees can expect a trade fair filled to the brim with current trends within the sectors and relevant cross-cutting technologies. This is the eighth hosting of the event in the optics hub, bringing together the cutting-edge technologies of optics, photonics, electronics, and precision engineering. The networking of these sectors boosts the sharing of knowledge and contacts between experts, so paving the way for new technology-driven innovations. Large-sized and smaller exhibitors such as Bühler Alzenau, Bruker, Carl Zeiss, Meopta, OptoTech, QED Technologies, Schunk, Trioptics, WZW Optic AG and others have confirmed their participation.

Other invited visitors include experts from application sectors such as medtech, life science, automotive, aerospace, tools and machinery as well as consumer electronics. At the EPIC TechWatch, the world's largest photonics industry association will provide enterprises with a platform on which to formulate their needs for advanced technology. EPIC is also the organizer of the C-Level Breakfast event.

The event organizer is taking no risks: the Covid safety plan is regularly updated in line with the latest local authority guidelines and includes the implementation of Germany's 2G rule (visitors must be vaccinated against or have recovered from Covid) as well as a corona-compliant floorplan.

www.w3-messe.de

Preview: LASER World of PHOTONICS

26 – 29 April 2022, Munich, Germany

The trade fair and congress for Photonics Components, Systems and Applications, has been setting standards since 1973 in size, diversity and relevance, with the combination of research, technology and applications.

In 2019, Laser World of Photonics and World of Photonics Congress saw 33,999 visitors from 82 countries, 1,325 exhibitors from 40 countries, 55,000 square meters total space, 6,717 congress and application panels participants, 3,635 congress lectures and presentations.

The trade fair and congress provide a more comprehensive, concentrated and transparent look at the world market than any other event, and feature a unique combination of research, innovative technology and industrial application sectors. And the entire range of solutions – from components to systems. The supporting program includes educational forums, panels and exclusive roundtable discussions with prominent participants from all branches of industry. The World of Photonics Congress is a unique networking and knowledge platform with user events that offer valuable know-how for your daily business.

According to the current regulations of the Free State of Bavaria as of mid-December 2021, trade fairs can take place. The VCR regulation applies for exhibitors and 2G plus regulation for visitors. The implementation of the new safety regulations is now planned for all upcoming trade fairs. Safe trade fairs are feasible for Messe München even in this pandemic situation.

Trade visitors attending on site in Munich will have to provide proof that they have either been vaccinated have recovered when registering. This is the result of the Bavarian State Government's requirement (§4). Visitors must present a valid negative test as well (rapid antigen test under supervision valid for 24 h / PCR test valid for 48 hours). This additional testing requirement does not apply to visitors who have had their booster vaccination more than 15 days ago. Access to the venue is only possible with an FFP2 mask.

https://world-of-photonics.com

15th International Laser Marketplace

Laser World of Photonics 2022 and Optech Consulting jointly stage the 15th International Laser Marketplace. The symposium will be held on Thursday, 28th April 2022, in conjunction with the Laser World of Photonics trade fair in Munich, Germany. Since its foundation in 1992 the symposium has attracted professionals and decision makers across the laser industry, from component and laser manufacturers to system integrators, end users, and investors.

www.lasermarketplace.de

Preview: AKL'22 International Laser Technology Congress

4 – 6 May 2022, Aachen, Germany

Laser manufacturers and users from various industries will meet for the 13th time at the AKL. Professor Constantin Häfner, director of the Fraunhofer Institute for Laser Technology ILT, will be pleased to welcome the laser community live in Aachen for AKL'22, particularly since the congress had to be canceled in 2020 due to the pandemic. 87 speakers will bring participants up to date on the current status and trends in laser technology in production.

The AKL congress has established itself in Europe as the leading forum for applied laser technology in production. Following its successful structure of previous years, the AKL'22 core conference will be accompanied on the first day May 4, 2022 by expert forums running in parallel that will dive deeply into the production topics of additive manufacturing, process monitoring and digitalization. In addition, Fraunhofer ILT will be devoting itself to photonic issues in quantum technology for the first time. This is an exciting new field that will also have a long-term impact on digitalization issues in production technology, such as the management of big data and AI.

Expert forums

The spectrum of research aspects in artificial intelligence (AI) ranges from machine learning in industrial practice to the use of augmented reality and data analysis with neural networks. However, AI is only a small component of the "Process Monitoring & Digitalization expert forum," which focuses on quality control and optimization of various laser manufacturing processes such as cutting, welding and additive manufacturing.

Participants of the "Laser Additive Manufacturing" expert forum will have the opportunity to spend the entire day learning about AM technology. Initially the focus will be on laser material deposition (LMD). The second part of the forum will focus on laser powder bed fusion (LPBF). The entire data chain must be considered for 3D printing to achieve a breakthrough in the manufacturing industry.

Quantum technologies are currently being advanced internationally at a cost of billions. Here we are at the beginning of a technical revolution that will enable fundamentally new applications. These include quantum imaging, quantum communication and quantum computing. Those interested in the current state of research and development can find out more at the "Quantum Technology" expert forum.

At the Technology Business Day, managing directors, marketing managers and strategists will receive an overview of the laser markets in Europe, Asia and America with an in-depth look at technological trends in e-mobility, micromanufacturing and 3D printing.

Register now for AKL'22 and take advantage of the early bird discount until March 4, 2022.

www.lasercongress.org

Preview: Control 2022

3 – 6 May 2022, Stuttgart, Germany

The 34th Control international trade fair for quality assurance is the unique business platform covering the fields of vision technology, image processing and sensor technology, as well as measuring and test technology. The booking status is extremely satisfying and the number of international participants is impressive. Not without reason: the significance of industrial quality assurance continues to grow and has never been more important than it is right now. Control is the leading technology, communication and business platform – which was forced to take a two-year break – that covers all aspects of quality control in industrial production. which was forced to take a 2-year break. The industry sector is now waiting to finally be able to meet again in Stuttgart. "Already 7 months before the trade fair opens, high booking levels amounting to more than 21,000 square metres of floor space have been reached, and 34 % of the exhibitors are from outside of Germany. This is unique!" says promoter P. E. Schall's managing director Bettina Schall.

"Industrial QA is gaining significance every day in all manufacturing industries and is now spreading into the service sector as well," emphasises project manager Fabian Krüger. "So it is high time to exchange views on QA in person again, and to discuss concrete solutions in an up-to-date setting. Exhibitors and expert visitors feel the very distinct need to see each other again in person and talk about innovations. Visitors are already asking for tickets."

www.control-messe.de

Preview: SENSOR+TEST 2022

10 – 12 May 2022, Nuremberg, Germany

After Sensor+Test was only allowed to take place digitally in 2020 and 2021, preparations for the return to a presence exhibition next spring are now in full swing. Experts will again meet in Nuremberg for an intensive exchange at the world's most important industrial fair for sensor and measurement technology.

Exhibitor interest in the event is already high six months before the start. "Hall 1 is already well filled and numerous companies are waiting to finally present their innovations again on site," explains Holger Bödeker, managing director of AMA Service GmbH.

For exhibitors, booking is risk-free: until the end of January 2022, the registration can be canceled free of charge. And if the exhibition is not allowed to take place in Nuremberg due to Covid-19, the costs for physical attendance will be fully refunded and the exhibitors will still benefit from the entire digital appearance at extremely favorable conditions," Bödeker explains

The special topic of Sensor+Test 2022 offers providers and users space for an innovation dialogue about new concepts, products and solutions for important areas of application: from human vital data and measured variables of our environment to the immense variety of data from industrial and technical processes. Companies and institutes with special expertise in digitization can present themselves with a cost-effective complete package at the special "Sensor and measurement technology for the digital world" forum. The lecture forum in Hall 1 on May 10, 2022 also has the motto "Sensor and measurement technology for the digital world".

www.sensor-test.com

Preview: Rapid.Tech 3D

17 – 19 May 2022, Erfurt, Germany

After two years without face-to-face interaction due to the pandemic, preparations are now in full swing for the next in-person meeting of the additive manufacturing family at Rapid.Tech 3D. Messe Erfurt will once again be welcoming innovators in person to the 18th edition of Germany's longest-standing AM trade fair.

"Industrial 3D printing has gained further impetus since 2019. Recent studies have shown that growth is continuing across all sectors. Stakeholders in development and application are keen to discuss new developments in AM – not via video conference but face-to-face, at in-person demonstrations and talks. So we are getting Rapid.Tech 3D ready for May, and we are looking forward to welcoming exhibitors and speakers, conference guests and exhibition visitors back to our grounds," says Michael Kynast. The Messe Erfurt CEO also points out that parts of the event will also be available online: "Key lectures from the specialist conference will also be streamed live so that we can deliver all the latest news from the world of AM to everyone who is interested, wherever they may be in the world."

The specialist conference remains the centerpiece of Rapid.Tech 3D 2022 and focuses on innovation, practical applications and the latest research. In addition to the keynote speeches and panel discussions, the world-class conference programme also includes over 70 lectures from industry and science. Two strands of the conference offer a variety of forums taking a user's eye view of issues currently affecting the additive industry and its customers, while a third strand presents the latest findings from AM research. In tried-and-tested fashion, the quality of contributions will be assured through double-blind reviews.

www.rapidtech-3d.com

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12 November 2021 Editorial deadline

Focus: Photonics West

- Laser sources
- Beam forming / beam analysis
- Optical components

SPIE. PHOTONICS WEST

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22 April 2022 Publishing date
22 March 2022 Advertising deadline
23 February 2022 Editorial deadline

Focus: Laser World of Photonics / AKL '22

- Ultrashort-pulse laser sources
- Laser materials processing
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LASER World of PHOTONICS
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15 June 2022 Publishing date
13 May 2022 Advertising deadline
18 April 2022 Editorial deadline

Focus: LASYS / SLT

- Laser systems
- Laser welding and cutting
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LASYS SLT 2022

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01 September 2022 Publishing date
01 August 2022 Advertising deadline
05 July 2022 Editorial deadline

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- Fibers and fiber optics
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- Additive manufacturing
- Laser plastics processing
- Laser welding und cutting

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05 October 2022 Editorial deadline

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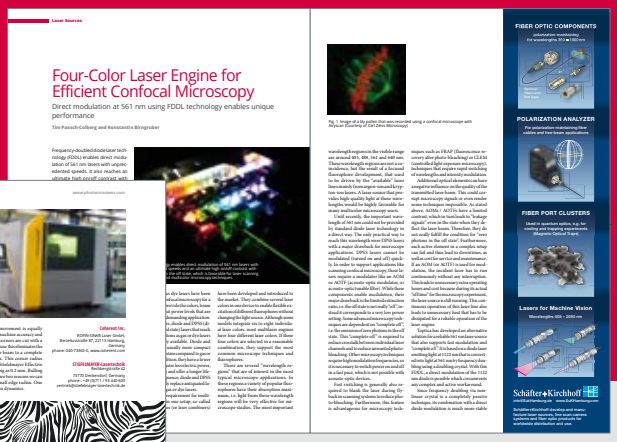
- Optical process controll
- Laser materials processing



Technical Article

"Full Paper" including company information box, author biographies, and contact addresses. Text 10,000 to 16,000 characters, 4 – 6 figures including one opening graphic or photography (300 dpi, or vector format)

Application Report

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

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Addressing a new device / technology with technical details / application example(s). Text 2,000 to 5,000 characters, 2 – 3 figures including one large format opening photography (300 dpi, or vector format)

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