Volume 21 February / March 2024

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PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY

FOCUS SECTION

Photonics for quantum technology

TECHNOLOGY FEATURE

Optical neurons to interconnect sensors and artificial brains in autonomous vehicles

OPTICAL MEASUREMENT TECHNOLOGY

Photonic blood glucose measurement with infrared quantum cascade lasers

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Can photonics drive the commercialization of quantum technologies?

The global quantum ecosystem gears up for transformative years ahead

Quantum technologies have a huge innovation potential and are set to revolutionize key sectors such as healthcare, finance, manufacturing, defense, and aerospace, offering advances in everyone's health, prosperity and security. We expect the market in 2024 to heat up with more commercial products.

Despite the value creation potential of quantum sensing, quantum communications and quantum computing of several trillion euros over the next ten years and immense private and government funding, only very few beneficiaries have developed a strategy to build up expertise and collaborations – the 'late follower' strategy could prove to be a dead end.

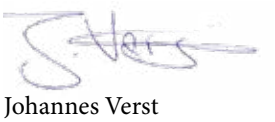
In 2024 we will see more quantum sensors that can yield unparalleled resolution revolutionizing, e.g., navigation and biomedical applications like brain imaging. The trend towards miniaturization and full integration of photonic components will further transform traditionally bulky systems, e.g., for quantum key distribution into affordable devices for the mass market. Furthermore, we'll probably see more R&D on fundamental concepts such as all-optical analog-to-digital converters paving the way to more efficient, low latency and high bandwidth applications in quantum communication and quantum computing systems.

Photonic quantum computers must meet initial benchmarks to remain competitive as the or one of the leading platforms. Advancements in quantum machine learning where quantum photonics platforms have already demonstrated notable speedup, especially when resources are limited, will gain momentum. In return, photonic component designers will be able to benefit from reinforced learning once QCs crosses the threshold into practical, real-world applications.

Quantum companies, end users, investors, and governments worldwide rely on QBN, recognized as the world's leading business network, think tank and nucleus of the global quantum ecosystem. They share our vision to 'establish quantum for good' to tackle global and societal challenges.

Let's build a resilient and sustainable quantum economy in 2024 and the years to come!

Yours sincerely



Johannes Verst

Source: QBN

Johannes Verst
CEO & Founder
Quantum Business Network

IQBN

PhotonicsViews
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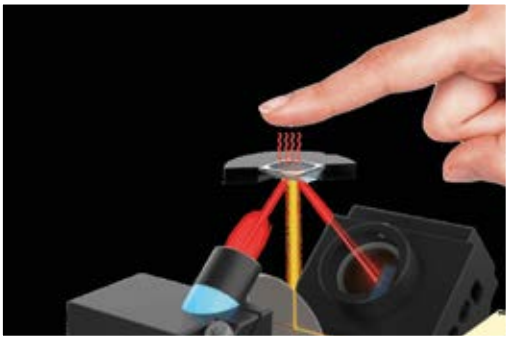

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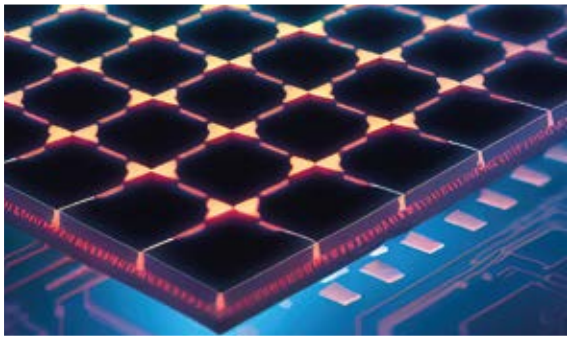


60 Advancements in hybrid photonics integration

Cover:

The JPT adjustable output beam (AOB) fiber laser has two coaxial beams, which can be controlled independently to optimize welding results, e.g., in battery manufacturing.

https://en.jptoe.com

Pulsar Photonics breaks ground for new headquarters

With a seven-figure investment, the laser technology company unites the different business areas at one new site. The new location at the Aachen Verlautenheide highway exit offers the urgently needed reserves for future growth and allows the consolidation of the business divisions at a joint location, strengthening their interaction.

The company's focus on modern working methods and technology increases flexibility and efficiency. This includes not only the design of the workspaces, but also the technological and digital infrastructure such as the expansion of fiber optic networks, the networking between the teams, or the implementation of modern in-house IT. At the same time, measures are planned to pave the way for a sustainable and energy-efficient orientation of the company.

L–r: Dr Stephan Eifel, Burkhardt Mohns (Walbert-Schmitz), Dr Joachim Ryll, Dr Jens Holtkamp on the site of the new headquarters in Aachen (Source: Pulsar Photonics)

A seven-figure investment is being made to construct the new building, which will later be used primarily for assembly and production. With a work and manufacturing area of around 1,600 square meters, the first construction phase of the new building should be completed and ready to move into by the end of 2024.

"Our aim is to become even more visible as a laser company in the region," says Dr Joachim Ryll, one of the three managing directors. "To this end, the new headquarters will be designed to be representative."

Pulsar Photonics has its current headquarters in Aachen-Herzogenrath and operates two further manufacturing sites in Aachen-Verlautenheide. The company was founded in 2013 as a spin-off of the Fraunhofer ILT in Aachen and was financed in its growth phase by the Hightech Gründerfonds HTGF, Bonn. With more than ninety employees today, it has belonged to the Schunk group since 2021.

www.pulsar-photonics.de

CeramOptec opens new location in Toronto for North America

The company, a pioneer in the field of optical fibers, opens a new location for North America in Toronto, Canada. For over thirty years, CeramOptec, which is part of the Biolitec group, has been delivering innovative solutions for a wide range of optical fiber applications in industries ranging from semiconductor to spectroscopy

CeramOptec manufactures fibers, fiber assemblies such as cables and bundles, and other products, many of which are tailored to meet the specific requirements of customer applications.

The new Toronto location will strengthen its presence in the marketplace, allow for closer collaboration with North American customers, and significantly reduce response time for product solutions. The facility will serve current and future customers from this strategic hub with sales, service, and technical expertise, creating a one-stop shop for all fiber optics needs.

Company founder and CEO of Biolitec, Dr Wolfgang Neuberger commented: "We chose Toronto as the location for our new North American headquarters because it is a leading tech hub with easy access to the entire continent. This new location will be instrumental in meeting customer needs since our representatives are now only a short distance away and customer engagement is especially important to us. As CeramOptec operates under one roof throughout the value chain, we can respond to customers' special wishes and implement individual solutions at any point in the production process."

www.ceramoptec.com

Evosys moves – in Germany and in the US

Source: Evosys

Production area in the new ELS building in Erlangen, Germany (Source: Evosys)

Due to the positive business development and the associated steady growth of the Evosys family, the subsidiary Evosys Laser Services GmbH in Erlangen, Germany, and the Evosys North America Corporation branch in the USA had to relocate.

In the United States, the initial move to the doubled office and production space took place at the beginning of May 2023. A half year later, half of the floor space has been converted into offices and meeting rooms, while the other half will be used as production and installation space.

The Evosys group currently consists of four companies: the parent company Evosys Laser GmbH, the subsidiary Evosys Laser Services GmbH and the subsidiaries Evosys (Suzhou) Laser System Co., Ltd. in China and Evosys North America Corporation in the US.

www.evosys-laser.com
www.evosys-laser.us

PI increases hexapod production

Physik Instrumente (PI) has increased production of its hexapods. They are in high demand.

The focus of the restructuring was the optimization and relocation of the entire hexapods production area to newly designed premises as well as an increase in personnel. The measures are part of the company-wide investment program with a volume of more than 63 million euros. This is intended to tap the above-average growth opportunities for PI in the markets of industrial automation, semiconductor manufacturing and photonics as well as microscopy and life sciences.

The factory layout for the new hexapod production was developed by PI experts, supported by specialists from the Fraunhofer Institute for Production Engineering and Automation IPA. It takes into account modern findings from ergonomics, digitalization, automation and lean approaches.

Source: PI

www.physikinstrumente.com

"Igniting the future of outdoor augmented reality"

The 'Quantum Light Chip' of Vienna-based start-up VitreaLab technology addresses the issue of brightness and energy efficiency in AR displays, enabling more vivid and longer-lasting AR experiences. Their innovation enables the creation of lightweight and compact AR glasses, overcoming the bulkiness of traditional AR headsets. The company has now received investment from PhotonVentures, targeting a leap in display technology and new AR and VR experiences.

This technology also promises to enhance the clarity and resolution of AR visuals, making them more realistic and immersive for everyday use across diverse sectors including medical, automotive, and mobile devices. The launch of a prototype is forthcoming, enabled not only by the financial support of PhotonVentures but also by the sustained investment from deep-tech funds Xista Science Ventures and Apex Ventures.

"PhotonVentures' expansive network and unparalleled expertise in the integrated photonics sector are positioned to significantly accelerate our technological advancements," states Chiara Greganti, co-founder of VitreaLab.

Pieter Klinkerts, partner at PhotonVentures, stresses the strong belief in VitreaLab's technology and is convinced that the potential of their technology will redefine the industry.

Source: PhotonVentures

Founders Jonas Zeuner and Chiara Greganti

https://vitrealab.com
https://photonventures.vc

Basler and MVTec will become part of the Siemens ecosystem

The new partnerships are intended to enable customers to integrate machine vision applications directly into their existing automation technology. From now on it will be possible to offer plug-and-play solutions for machine vision – a suitable portfolio of automation and image processing components, consisting of hardware and software.

Integrating cameras into automation is considered cumbersome and requires a high level of specific knowledge in order to coordinate compatible components. This is associated with high costs and is often implemented on independent 'islands' – e.g. dedicated industrial PCs. The collaboration between the three companies is intended to reduce complexity for customers and thus significantly lower the entry barrier for integrating machine vision solutions into their machines and systems.

"Together with our new partners in the open Siemens Xcelerator ecosystem, we are integrating industrial image processing into automation. This helps with many tasks, for example when it comes to difficult quality control or reducing errors and subsequent waste in industrial production. "We are taking an important step towards adaptable, sustainable production and increasingly autonomous production processes," says Rainer Brehm, CEO factory automation at Siemens.

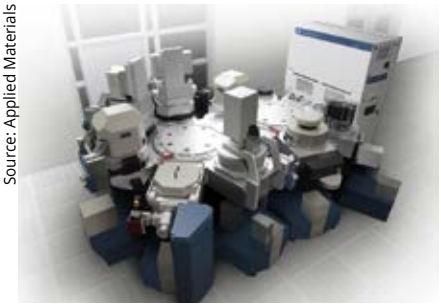
www.siemens.de ■ www.mvtec.com
www.baslerweb.com

Source: Siemens

Announced the partnerships at the SPS, l–r: Dr Olaf Munkelt, MVTec, Rainer Brehm, Siemens, and Dr Dietmar Ley, Basler

Applied Materials and CEA-Leti unveil joint lab

Source: Applied Materials



Endura system in the joint lab of Applied Materials and CEA-Leti

Based at CEA-Leti, the new lab aims to accelerate device innovations for Applied Materials' customers serving ICAPS markets – IoT, communications, automotive, power and sensors. Technology applications in those fields include photonics, image sensors, RF communications components, power devices and heterogeneous integration.

Demand for ICAPS applications and devices is being driven by industrial automation, the Internet of Things, electric vehicles, green energy and smart grid infrastructure, among other major high growth markets. Projects at the joint lab will focus on developing solutions for a variety of materials engineering challenges to enable the next wave of ICAPS device innovation. The joint lab features several of Applied Materials' 200 and 300 mm wafer processing systems and leverages CEA-Leti's world-class capabilities of evaluating new materials' performance and device validation. Improvements in power consumption, performance and area/cost, along with a faster time to market (PPACt), will be key objectives of the joint team.

"For the past ten years, Applied Materials and CEA-Leti have collaborated through multiple, specific joint development programs, which have set the stage for establishing our new joint lab. In addition to developing differentiated technological solutions for Applied Materials' customers, the work performed at the joint lab will help overcome current technical hurdles in support of CEA-Leti's internal R&D programs," said Sébastian Dauvé, the institute's CEO.

www.appliedmaterials.com
www.leti-cea.com

KCOP: a high-tech center for KIT

The Karlsruhe Center for Optics and Photonics (KCOP) is taking shape. At the new, highly modern technology center of Karlsruhe Institute of Technology (KIT), research teams will work on applications of light or photons. These include highly efficient photovoltaics, 6G communication and glass fiber networks, novel quantum sensors, superconducting detectors, extremely fast 3D image acquisition, and high-resolution microscopy for life sciences. The 56 million euro building is planned to be inaugurated in early 2026.

KCOP will now set new standards and use synergies. "As of 2026, research teams will use an internationally outstanding technology platform with about 2,000 square meters of clean rooms and laboratory areas and a pool of instruments. Thanks to their joint use, more efficient operation will be possible," Christian Koos summarizes. He is professor at the Institute of Photonics and Quantum Electronics and at the Institute of Microstructure Technology of KIT as well as scientific director of KCOP.

Apart from Karlsruhe, there are only a few places in Europe where degree programs are offered in optics and photonics.

At KCOP, researchers of various disciplines will meet and discuss under one roof. The technology center will mainly be available to the institutes of KIT, but external research teams will also be given the opportunity to work there. The planned fields of work will include renewable energies, novel communication technologies, quantum components, life sciences, digital fabrication on the nanoscale, and customized materials.

www.kit.edu

Project Q-net-Q: a quantum highway for Germany between Berlin and Frankfurt

Thuringia's science minister Wolfgang Tiefensee in conversation with the researchers in a Fraunhofer lab (Source: Fh. IOF)

The Free State of Thuringia is about to become an important hub for the German quantum network. Existing test links for researching quantum-secured fiber links between Erfurt and Jena are now to be extended by new sections in the direction of Nordhausen and, later, Berlin and Frankfurt.

An optical fiber test link has already been established between the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena and the Fraunhofer Center in Erfurt with funding from the state. Quantum keys have already been successfully exchanged between Thuringia's metropolitan cities over a distance of 75 kilometers as part of the QuNET initiative funded by the German Federal Ministry of Education and Research, BMBF. It was possible to use the existing infrastructure of conventional telecommunications fiber optics for the test link.

The Thuringian communities of Nordhausen and Sundhausen will be connected to the existing link between Jena and Erfurt by 2024. The University Hospital in Jena will also be connected to the test link. This will extend the fiber-based test route to a length of more than 150 kilometers. Further sections are planned as far as Berlin and Frankfurt am Main by the end of 2024. The go-ahead was given by Thuringia's Science Minister Wolfgang Tiefensee in August 2023 during a visit to the Fraunhofer Center in Erfurt.

The Q-net-Q project is being implemented as part of the European EuroQCI program.

www.iof.fraunhofer.de

Over $10M invested in quantum communication testbed

The non-profit organization Numana has launched a multipurpose project for quantum-safe communications across three cities in Quebec, Canada, with two objectives. The first is to provide the necessary infrastructure to test emerging quantum communications technologies. Secondly, this testbed could become one of the cornerstones of a future nationwide quantum communication network, as outlined in Canada's National Quantum Strategy.

Source: Numana

Ms Soraya Martinez Ferrara, Minister of Tourism and Minister of Economic Development for the region of Quebec, Government of Canada, and Mr François Borrelli, CEO of Numana.

Organizations developing quantum-safe communications can now begin testing their products on the first node of the testbed, which is now live in the city of Sherbrooke. Additional nodes in Montreal and Quebec City will be brought online early in the new year. Each city will offer systems with different features, and new technologies will be added as they become available, keeping the testbed up to date.

"Unlike projects built by private companies for their own exclusive use, this project will allow us to welcome innovators from all over the world who are looking for a place to test their quantum-safe technologies. This is but one of the ways we are working to develop the quantum industry in Quebec," said Francois Borrelli, CEO of Numana.

The testbed is available to startups, researchers, small business, large corporations, and other actors, both domestic and foreign. It allows these stakeholders to experiment with the use of quantum-safe communications by testing new technologies without disrupting the existing infrastructure. It is believed that this work, and the partnerships that will develop through the use of this testbed, will have a significant economic impact for Quebec and Canada, and potentially attract a cluster of startups in the industry to the area.

Canadian telecom companies Bell Canada and Telus are providing access to their fiber optic networks. These network operators can also develop, design, and test their own quantum capabilities while collaborating with researchers and startups. When used in conjunction with quantum communications technologies such as QKD systems, this infrastructure has the potential to unlock new applications in a range of industries such as health care, finance, transportation, and defense, among others.

https://numana.tech

Funding award for bringing quantum computing to light

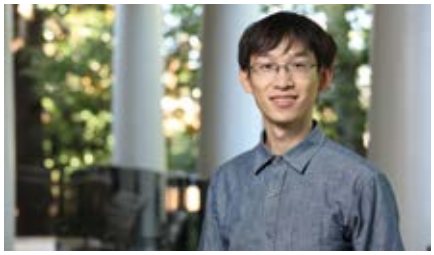
The University of Virginia's associate professor Xu Yi received a 550,000 dollar National Science Foundation Career Award to explore the use of quantum optical technology to try to solve the problems of scalability and error resilience.

While quantum computing front-runners like IBM and Google are using superconducting circuits as processors to manipulate and store quantum information, the metal materials used to construct these components offer too many opportunities for error in computations.

That is why Yi aims to leverage photons to greatly reduce the number of physical components needed for quantum operations. His work uses optical components that can each support hundreds of thousands of wavelength messages. With fewer components, Yi's system greatly reduces opportunities for error while offering a vehicle for scaling.

Photonic quantum computing was first developed at UVA by physics professor Oliver Pfister on a tabletop more than ten years ago. When Yi can prove the same entanglement capability at chip scale that Pfister proved at tabletop scale, he will start controlling the wavelengths for computations and then expand and scale.

https://engineering.virginia.edu



Prof Xu Yi
(Source: U Virginia)

ALSO OF INTEREST

Your daily quantum of photonics news

WIN NEWS

BitFlow to be acquired by Advantech

Agreement for an all-cash transaction representing a 100 % equity stake.

Siemens publishes Infrastructure Transition Monitor 2023

According to the study, only 37 % of companies in Germany, Austria and Switzerland expect to achieve their decarbonization goals by 2030.

SLAC brings rapid-fire laser and target expertise to fusion energy

The Department of Energy's laboratory and Stanford will partner with other institutions in the creation of two inertial fusion science and technology hubs.

Lights out!

The Swiss Light Source will shut down temporarily as part of a major upgrade project. It will come back online in 2025.

Jenoptik increases sales and incoming orders

The photonics group continued on its growth path.

Stemmer Imaging and Aetina Europe start partnership

The aim of the collaboration is to advance embedded vision on the market.

Fisba and Gray Optics move in together in Maine

Fisba has acquired Gray Optics, a developer of precision optical systems, in North America.

Smart Vision Lights announces UR+ certification

Universal Robots acknowledges Smart Vision Lights' DoAll multifunctional light.

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WIN NEWS

75,000 dollars for non-invasive brain monitoring

Mahler in the lab, working on the multichannel helmet (Source: SPIE)

Simon Mahler is the winner of the SPIE' postdoctoral fellowship in problem-driven biomedical optics and analytics. The annual award of 75,000 dollars named after German medical laser pioneer Franz Hillenkamp supports interdisciplinary problem-driven research and provides opportunities to translate new technologies into clinical practice that improves human health. Mahler, who received his PhD in nonlinear optics from the Weizmann Institute of Science in 2021, will be recognized at the SPIE BiOS Hot Topics event during Photonics West.

His postdoctoral research, conducted in conjunction with Changhuei Yang at Caltech's biophotonics lab, focuses on designing a multichannel device, using infrared laser speckle imaging, that non-invasively monitors cerebral blood flow in the human head across several locations simultaneously. Leveraging this technology could advance certain medical applications, including the diagnosis of traumatic brain injuries such as concussion.

"This opportunity prompts me to expand my horizons and immerse myself in a biomedical engineering research environment. I hope to gain valuable insights in the coming years, enabling me to leverage technology and potentially contribute to the advancement of medical applications," said Mahler.

https://spie.org

New CEO and CTO for Bia Analytical

Simon Cole and Gareth Burns join after a successful investment round involving an outstanding collection of new strategically significant partners. Emerging from the Queen's University Belfast's Institute for Global Food Security (IGFS), Bia Analytical was launched as a start-up venture in spring 2020, led by founder Prof Chris Elliott, with a focus on identifying and reducing the major problem of food fraud across the globe. Spearheaded by Richard Ilsley and Dr Terry McGrath, the company has since its inception focused upon proof-of-concept work in food authentication, initially in the herb and spice arena, subsequently evolving into additional larger food groups such as cereals and meat. This work has seen Bia Analytical develop a revolutionary portable solution for in-situ testing as well as ground-breaking cloud-based applications.

Source: Bia Analytical

l–r: Dr Terry McGrath, Gareth Burns, Simon Cole

Now the company has appointed Simon Cole as CEO and Gareth Burns as CTO. Simon has worked in the software and technology industry for over 25 years, and was a founder and most recently CEO of Automated Intelligence Ltd. Gareth is an experienced start-up co-founder in the software industry. Co-founder of Bia Analytical, Dr Terry McGrath, completes the management board as chief science officer.

Richard Ilsley will cease to be CEO of Bia following these appointments and the board and shareholders put on record their appreciation for his diligent and effective leadership and smooth handover to Simon.

Accompanying these key appointments, Bia Analytical also announces the completion of a successful funding round that includes key complementary investors to support the company's advancement. Investors in Bia Analytical include leaders in the food and consumer science worlds – Oritain, Cranswick, Fayrefield Foods, Qubis and Veetee Rice – plus entrepreneurs, innovators and investors including Andrew and Angela Higginson, Tom Singh, Charles Wilson, and Andrew Xeni.

Commenting upon these recent developments, Bia Analytical chair, Dr Clive Black, stated: "The company was born from a world-class food science resource to take its first steps in addressing more accurately, quickly, and efficiently the growing challenges of food fraud, integrity, and safety across the globe. Under Richard and Terry, whom I sincerely thank, the concept has been proven and with the additional experience and capability of Simon and Gareth on board, we are primed to go through our next phases of our growth, including in wider product silos such as apparel."

https://bia-analytical.com

Zebra Technologies appoints new CRO

Source: Zebra Technologies

Richard Hudson

New chief revenue officer for Zebra Technologies is Richard Hudson who previously served as senior vice president and general manager for the Europe, Middle East and Africa (EMEA) region. He succeeds Joe Heel, who has served as the company's CRO since 2014.

With over twenty years of sales experience in the technology sector, Hudson joined Zebra in 2014 as part of the acquisition of Motorola Solutions' enterprise business. Prior to Zebra, Hudson held various positions of increasing responsibility, including vice president, EMEA Channels and Solutions at Motorola. Hudson received his bachelor's degree in mechanical engineering from Brunel University London.

www.zebra.com

Take 5: new laser, photonics, quantum experts for Acatech

A total of 39 scientists have been newly elected into Germany's National Academy of Science and Engineering. Acatech unites more than six hundred individuals from science and industry as the national academy and voice of engineering in Germany and on an international level. Its members are admitted to the academy on the basis of their scientific achievements and reputation. They come from the fields of engineering, natural sciences, medicine, and humanities and social sciences.

At this year's annual meeting, there were five experts for laser, photonics, and quantum physics among the newly elected academy members:

Source: U Paderborn

Prof Christine Silberhorn

Source: TU Dresden

Prof Andrés Fabian Lasagni

Source: Wiley / Weber-Shandwick

Heike Riel

Andrés Lasagni is a professor at TU Dresden since 2012 and coordinator of the Center for Advanced Micro-Photonics (CAMP) at the Fraunhofer Institute for Material and Beam Technology IWS in Dresden since 2017. Born in Argentina, he began his academic career with a degree in chemical engineering at the National University of Comahue in Argentina and completed his doctorate in materials science at Saarland University, Germany, in 2006. After a research stay in the USA, he came to Dresden in 2008 to set up a research group at the Fraunhofer IWS. Lasagni researches industrial solutions for surface functionalization using laser technology.

Heike Riel is an IBM Fellow, head of science and technology and lead of IBM Research Quantum Europe, responsible for leading the research agenda of the science and technology department. This aims to create scientific and technological breakthroughs in quantum computing, physics of artificial intelligence, nanoscience and nanotechnology, precision diagnostics and smart system integration. She also serves as the deputy director of the new Swiss National Competence Center for Research on Silicon Spin Qubits.

Piet Oliver Schmidt is a professor at Hannover University and the PTB in Braunschweig where he heads the Institute for Experimental Quantum Metrology. He studied physics in Constance and Portland and received his doctorate from the University of Stuttgart in 2003. From 2005 to 2008 he was assistant to Rainer Blatt and was appointed professor in 2009.

Sebastian M Schmidt studied theoretical physics in Rostock and Dubna and is an expert for quantum chromodynamics and quantum electrodynamics. He received a Minerva stipend from the University of Tel Aviv as well as a stipend from the Alexander von Humboldt Foundation to work at the Argonne National Laboratory. From 2002 to 2006, Schmidt was employed at the later appointed managing director of the Helmholtz Association headquarters in Berlin. In 2020, he became scientific director of the Helmholtz Zentrum Dresden-Rossendorf (HZDR).

Christine Silberhorn is currently chair for integrated quantum optics and head of the Institute for Photonic Quantum Systems at Paderborn University. The physicist was awarded the Leibniz Prize in 2011 and was the youngest recipient of the 2.5 million euro prize at that time. (Sources: Acatech / HZDR / IBM / LUH / TU Dresden / U Paderborn)

www.acatech.de

https://tu-dresden.de

Femtowatt photo receivers, an alternative to PMT and APD

Manufacturer: Femto Messtechnik
Product: Extremely low-noise photo receivers of the 'FWPR-20' series for the wavelength range from 320 nm to 1700 nm with 20 Hz bandwidth and integrated signal amplification up to 10^{12} V/A
Features: The femtowatt photoreceivers combine large-area Si-PIN or InGaAs-PIN photodiodes with extremely low-noise transimpedance amplifiers. The NEP is only 0.7 fW/√Hz and enables direct measurement of optical power down to the femtowatt range with a digital voltmeter. In combination with a lock-in amplifier, modulated AC measurements down to the sub-femtowatt range can also be easily made. High quantum efficiency, robustness against optical overload and the compact design make these photo receivers a good alternative to photomultipliers (PMT), avalanche photodiodes (APD), or cooled germanium detectors in many applications. In non-time-critical applications with acquisition times of more than 100 ms, the photoreceivers even achieve better noise values than many APD receivers because the excess noise factor, which is unavoidable in APDs, does not occur.

Source: FEMTO Messtechnik

The free space models with a 1.035"-40 thread (FST) are very versatile as they can be converted into a fiber-coupled version in no time.
Applications: Replacement of APDs, PMTs, or cooled Ge detectors in non-time-critical measurements. Measurement of extremely small optical powers in spectroscopy, electrophoresis, chromatography, fluorescence and much more.

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Web: www.femto.de

Light measurement technology for a perfect AR/VR world

Instrument Systems will be presenting its portfolio for the optical quality assurance of AR/VR devices along the entire production chain at SPIE Photonics West and AR|VR|MR 2024.
The new 'LumiTop 5300' AR/VR color measurement camera meets the very specific test requirements for displays in AR/VR headsets and is optimized for near-eye display testing. Its lens reproduces the human eye as realistically as possible and measures color and luminance as the user sees it. The camera has a very high resolution of 24 MP and a large field-of-view of 122° × 107°. This allows most headset displays to be captured in high quality with just a single shot. The straight lens is perfect for testing AR/VR display modules in the production line before mounting them in the headset.


Source: Instrument Systems

The proven 'LumiTop 4000' AR/VR system with 12 MP resolution is ideal for quality control at the end of the production chain. A periscope lens imitates the human eye pupil and provides easy access to measure the final headset displays.
The new 'Top 300' color and luminance measurement system is designed as a production test system in combination with a CAS spectroradiometer. These coupling optics provide an optical system modeled on the human eye and an integrated viewfinder camera. The system is specifically designed for simple optical testing of the color and luminance of AR/VR modules and is a cost-effective alternative to color measurement cameras for module-level testing.
Instrument Systems will be complementing its product presentations with three scientific expert lectures on quality control at different stages of AR/VR headset production, together with LIV characterization and eye safety testing of VCSELs (Sessions: 12904-11, 12913-55, 12913-45).

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Web: www.instrumentsystems.com
Photonics West, Booth 6101 and 4205-12

Optical seam sensor for automated welding

Source: Scansonic

Manufacturer: Scansonic
Product: New model 'TH6D-Advanced' in the product family of optical seam sensors with extremely powerful image processing and scalable pattern recognition algorithms. The sensor is suitable for applications in automated arc or laser welding processes, as well as for automated gluing or other processes where precise and reliable guidance along a defined geometry is required.
Features: The basis of image processing in the new sensor is the proven triangulation principle. Components and various joints are detected by combining laser beams, a powerful camera and an optical system. The sensor detects all common seam shapes and can be used for all materials that can be joined or separated, such as steel, stainless steel, aluminum, plastics or wood. The supplied software is quickly installed and extremely user-friendly. The customer can easily adapt it to his own individual processes and specific seam geometry. The permanent tuning eliminates the need for time-consuming re-teaching when changing parts or if there are changes in the edge. Thanks to its robust design, the new system works even under conditions of highly automated series production. It is insensitive to the influence of electrical interference. The housing is splash-proof and features an integrated protective glass rinsing system and a protective glass quick-change unit. An integrated air cooling system ensures constant temperatures. This makes the new system ideal for both small and medium-sized companies that want to automate their joining processes or improve existing ones.

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World's first portable wideband laser

Manufacturer: SuperLight Photonics
Product: Portable wideband laser SLP-1000 with smooth, wide spectral output that provides high-quality nonlinear pulse compression for application fields such as third harmonic surface imaging and transient absorption spectroscopy.
Background: Supercontinuum lasers, also known as wideband lasers, provide immense bandwidth while maintaining high coherence and low noise. However, today's industrial solutions are large and heavy, with limited environmental robustness, and require high power. While they deliver a wide bandwidth of colors, a dominant color usually stands out, whereas the remaining colors are at exceedingly low relative power levels.
Features: The new model is an industry-first portable wideband laser with a compact, battery-operated, and rugged design, weighing only 900 grams (32 oz) and with a form factor of less than one liter. Based on PAD (patterned alternating dispersion), it offers a coherent and stable spectral output (400 nm @ –3 dB, 1500 nm @ –20 dB) in the NIR band at a repetition rate of 100 MHz with pulse durations of around 20 fs. It contains a seed laser from Menlo Systems. The laser output is equipped with a Thorlabs-compatible screw thread (SM05), seamlessly integrating with other products from Thorlabs.

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Clearer images for oncologists

New imaging technique combines ultrasound and optical tomography to help doctors make diagnoses

A multidisciplinary team lead by Souvik Roy, University of Texas at Arlington, is on a mission to improve medical imaging using a new technique called quantitative photoacoustic tomography (QPAT). This type of imaging combines ultrasound, which is an imaging technique that uses sound waves to image features inside the body, and optical tomography. It uses acoustic wave intensity data measured on the surface of the body through a scanner composed of acoustic wave detectors. This enables the development of images of various optical properties of tissues, like absorption and diffusion, which can provide crucial information about the location and stage of a cancerous tissue.

"QPAT is robust because it uses information from two imaging techniques and has the potential to provide high-quality images. It can tell us so much more about what's going on under the skin," Roy said. "By providing better images, doctors will be able to make more accurate diagnoses in shorter time frames. This will lessen anxiety for patients as well as decrease costs for the health care industry by reducing the need for repeated scans." One of the major challenges in developing QPAT is the lack of adequate acoustic wave measurements on the surface of the body, which can significantly degrade the quality of the images and result in inaccurate diagnosis of cancerous tumors. To circumvent this issue, Roy and his team – comprising statistician co-principal investigator Suvra Pal and radiologists – have received a $190,000 grant from the National Science Foundation to significantly develop and improve the QPAT imaging technique.

The team will use a novel combination of game theory, statistical sensitivity analysis and gradient-free optimal control methods to help complete the missing acoustic wave measurements and stabilize and recalibrate computational algorithms to provide high-contrast and high-resolution images. "We hope to facilitate a safe start to research on imaging human subjects using QPAT," Roy said. "Our ultimate goal is to develop more accurate images in a shorter timeframe, and to help patients get better. These enhanced scans should help doctors and patients make better health care treatment decisions. Down the line, we know this will improve outcomes, reduce patient anxiety and be highly cost-effective."

Source: UTA

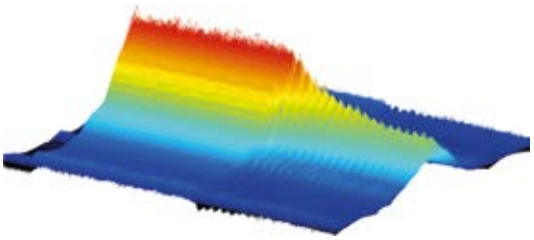
Souvik Roy

www.uta.edu

New frequency comb identifies molecules faster

Laser-based system captures moment-to-moment details of high-speed processes such as protein folding

From monitoring concentrations of greenhouse gases to detecting Covid in the breath, frequency combs can identify specific molecules as simple as carbon dioxide and as complex as monoclonal antibodies with unprecedented accuracy and sensitivity. However, frequency combs have been limited in how fast they can capture a high-speed process such as hypersonic propulsion or the folding of proteins in their three-dimensional shapes. Now, researchers at the National Institute of Standards and Technology (NIST), Toptica Photonics and the University of Colorado Boulder have developed a frequency comb system that can detect the presence of specific molecules in a sample every twenty nanoseconds.



A new frequency comb setup can capture the moment-by-moment details of carbon dioxide gas escaping from a nozzle at supersonic speeds in an air-filled chamber, followed by rapid oscillations of gas due to complex aerodynamics within the chamber. (Source: G. Mathews, U Colorado)

With this new capability, researchers can potentially use frequency combs to better understand the split-second intermediate steps in fast-moving processes ranging from the workings of hypersonic jet engines to the chemical reactions between enzymes that regulate cell growth. In their experiment, the researchers used the now-common dual-frequency comb setup, which contains two laser beams that work together to detect the spectrum of colors that a molecule absorbs. Most dual-frequency comb setups involve two femtosecond lasers, which send out a pair of ultrafast pulses in lockstep. In this new experiment, the researchers used a simpler and cheaper setup of electro-optic combs, in which a single continuous beam of light first gets split into two beams. Then, an electronic modulator produces electric fields that alter both light beams, shaping them into the individual teeth of a frequency comb. Each tooth is a specific color or frequency of light that can then be absorbed by a molecule of interest.

Whereas conventional frequency combs can have thousands or even millions of teeth, the researchers' electro-optic comb only had fourteen in a typical experimental run. However, as a result, each tooth had much higher optical power, and was far apart from others in frequency, resulting in a clear, strong signal that enabled the researchers to detect changes in the absorption of light at the 20-ns time scale. (Source: NIST)

Reference: *D. A. Long* et al.: Nanosecond time-resolved dual-comb absorption spectroscopy, Nat. Phot., online 30 October 2023, DOI: 10.1038/s41566-023-01316-8

How label-free, super-resolution imaging will push microscopy's limits

Roadmap: new research lays out the future of a pioneering form of electromagnetic imaging

Elements of living things with sizes smaller than around 10 nm, such as enzymes and DNA, require electron microscopy to be seen. Yet optical microscopes are preferable over electron microscopes because of their non-invasive nature when it comes to seeing within living things and observing cells and tissues to understand the processes that occur there.

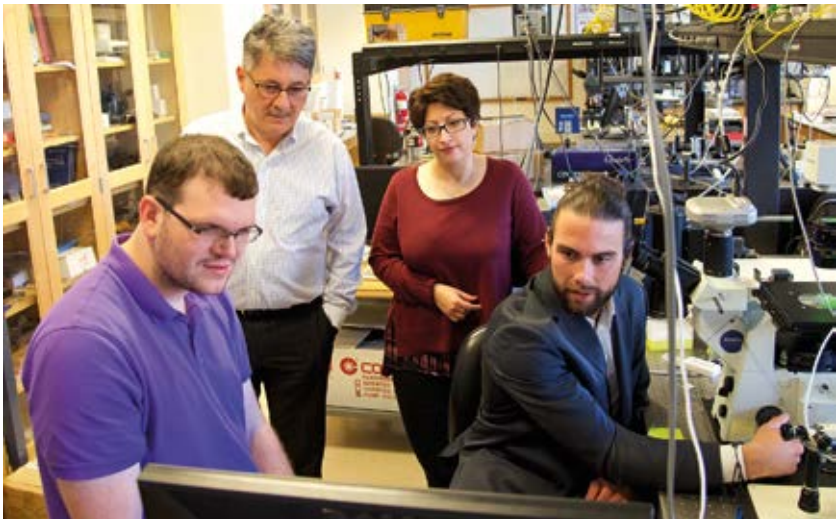
Bright fluorescent markers such as dye molecules can be used for the specific labeling of sub-cellular structures and, hence, cellular functions and thereby push optical microscopes past the diffraction limit, but this has drawbacks. Not only is labeling of this type not suitable in all circumstances, but it can also be difficult to achieve. Additionally, labeling can lead to photo-toxicity that can damage living cells or tissues.

Scientists are therefore interested in methods that can push optical microscopy without the need for dyes. Label-free super-resolution (LFSR) imaging relies on light scattering processes in nanoscale materials without the need for bright fluorescent markers.

"The label-free imaging is a type of optical microscopy or, in a broader sense, a type of electromagnetic imaging, which does not rely on the use of bright fluorescent markers such as dye molecules added to investigated biomedical or other structures to increase their contrast or to highlight particular structures of interest," said Vasily Astratov, University of North Carolina at Charlotte, professor of physics and optical science.

"This is a much-needed type of imaging in biomedical applications, but it pushes our understanding of underlying physical mechanisms beyond the classical diffraction due to such factors as the fundamental role of noise and information capacity of the optical system, the role of prior knowledge and AI science, near-field and nonlinear optics, as well as advanced superlens designs," he continued.

The challenges that LFSR presents as it grows as a microscopy technique prompted Astratov and colleagues across 27 teams of researchers to create a roadmap for the future development of this process. The work of the team and their conclusions are documented in a 104-page paper published in the journal Laser & Photonics Reviews with a foreword by Sir John Pendry of Imperial College London.



The Mesoscale Photonics Lab team in 2017 with their microsphere-assisted setup for superresolution imaging, l–r: Aaron Brettin, Prof Vasily Astratov, Farzaneh Abolmaali, Kylen Blanchette (Source: UNC Charlotte, Lynn Roberson)

Astratov explained that this roadmap represents a first-of-its-kind vision of the past, present, and future developments in this area based on the physical mechanisms of LFSR imaging.

A roadmap into the nanoscale

Initially, the development of LFSR imaging was a gradual process based on introducing novel physical mechanisms to each other across a range of interdisciplinary concepts. The development of LFSR burgeoned in the last two decades thanks to three major developments.

The first of these was the realization that imaging is a problem that can be tackled by machine learning using different forms of prior knowledge about objects, training of imaging systems considered to be deep-learning networks, and, finally, using artificial intelligence to recognize images and improve the resolution of optical instruments.

Second was the development of structured illumination microscopy – the use of structured illumination, such as interference patterns between wavelengths of light, to make high spatial frequencies visible to microscopes. The third vital aspect was the development of novel optical concepts such as 'perfect lenses', superlenses, and hyperlenses, as well as the development of transformation optics in the context of metamaterials and other substances.

Research co-author and UCLA professor Aydogan Ozcan pointed out it is these developments that caused an explosive growth of LFSR imaging.

"To some extent, this is similar to the revolution we experience in everyday life as a result of the explosive growth of more general AI ideas, which reached the point of consideration and concern," Ozcan said. "In the case of LFSR imaging, it is not a concern, but rather a combination of explosive growth and lack of methodology and systematic approach to this field that created an urgent need to develop a vision of the future of this field in general and for this roadmap in particular."

He added that in the past, studies of LFSP imaging were conducted in physics and biomedical optics communities, which have separate conferences and different research priorities. The aim of Astratov and colleagues was to instead bring communities under the same umbrella and create synergistic interaction between approaches to LFSR. (Source: Advanced Science News, Robert Lea)

Reference: *V. N. Astratov* et al.: Roadmap on Label-Free Super-Resolution Imaging, Laser & Photonics Reviews, (2023), DOI: 10.1002/lpor.202200029

Breaking the limits of high-resolution VR displays

New technology reduces the visibility of the annoying grid pattern on virtual reality screens

People want VR experiences to feel even more realistic and immersive. However, the screen door effect has been a hindrance to achieving this immersion. This effect is like looking through a screen door, where users see a grid-like pattern on VR screens due to low resolution problems, which diminishes the overall visual quality. To overcome this challenge, VR displays have undergone significant enhancements in various specifications, including resolution, color quality, and response speed.

The VR displays available now typically have resolutions of around 1200 PPI, which still have room for improvement. Enter the proposed 2117 PPI 4K VR LCD, a promising solution that offers better image quality. Moreover, VR LCDs with high partition mini LED backlighting have demonstrated substantial improvements in contrast, color accuracy, and viewing angles, placing them in direct competition with the esteemed micro-OLED displays. When it comes to choosing the right display technology for VR applications, each has its unique advantages and drawbacks.

Micro-OLED displays, especially the ones built on silicon, provide VR experiences with very high resolution. However, they are quite expensive and require more complex optical designs compared to LCDs because of their small size. On the other hand, VR LCDs excel in providing a broader field of view (FOV) despite facing challenges related to color contrast and pixel size. The integration of mini-LED backlighting has boosted LCD performance, making it competitive with micro OLED, especially in terms of response time, contrast, luminance, and lifespan. LCDs shine in their ability to deliver larger panel sizes, enhancing the immersive VR experience. In contrast, Micro-OLED and Micro-LED displays are made for high-end markets, but they are quite expensive. In contrast, LCDs are a more affordable choice, making them accessible to a wider range of people.

2.56-inch 4K VR LCD single-piece display demonstration (Source: Y.-H. Wu et al.)

Advancements in VR display technology extend beyond the realm of gaming and entertainment. They find application in various industries, such as healthcare, where high-quality VR displays are used in medical training simulations, enabling professionals to practice surgeries and procedures realistically. In the automotive sector, VR displays play a pivotal role in designing and testing vehicle interiors and user interfaces. Architectural firms harness VR technology to create immersive virtual walkthroughs of building designs, offering clients a lifelike preview of their projects.

The recent research by Yung-Hsun Wu of Innolux Technology Development Center and colleagues introduces an exciting advancement in high-quality virtual reality displays, specifically a 2117-ppi LCD. This technology brings significant improvements, making VR experiences more immersive by enhancing the range of colors and reducing the annoying 'screen door' effect where you see a grid on the screen. The research paper explores the challenges and potential solutions of creating LCDs with over 2000-ppi resolution. It discusses how to design pixels to make them work better, increase the efficiency of the liquid crystal used in the display, and improve how much light gets through. Additionally, the paper suggests using mini-LED backlight and low-power solutions to make sure these high-resolution displays maintain excellent image quality while using less energy. (Source: SPIE)

Reference: *Y.-H. Wu* et al.: Breaking the limits of virtual reality display resolution: the advancements of a 2117-pixels per inch 4K virtual reality liquid crystal display, J. Opt. Microsys. **3**, 041208 (2023); DOI: 10.1117/1.jom.3.4.041208

www.innolux.com

Mikrotron camera tests AR headset to prevent falls

New augmented reality-assistive headset designed to teach older adults how to improve balance

Falls are a major health concern, especially for those 65 and older. The US Centers for Disease Control and Prevention (CDC) has revealed that 20 % of falls lead to an injury such as a broken hip. In fact, more than three million older Americans annually are treated in emergency rooms for fall injuries. Degenerative processes underlying aging are the central cause of the increase in fall risk and injuries. The National Council on Aging, the Administration for Community Living, and other groups offer support for initiatives designed to reduce the occurrence of falls. Different training approaches aim to improve balance in older people. The most current advancements in prevention training involve augmented reality (AR) and virtual reality (VR) headsets.

These devices create immersive, realistic scenarios that challenge the user without compromising safety. Wearable AR and VR headsets teach users to spot visual cues that provide a continuous space-stationary reference frame for


Source: SVS-Vistek
Mikrotron mini2 CMOS camera

balance control, helping them maintain an upright position and prevent falls in daily life. Scientists at the University of Konstanz, Germany, recently filed for a patent for a new AR-assistive wearable headset designed to teach older adults how to improve their balance. Dubbed MoPeDT, the custom head-mounted display toolkit presents augmented visual orientation cues (AVOC) in the peripheral field of view.

The University of Konstanz scientists conducted a series of balance experiments to examine the impact of visible cues on body sway, a contributor to falls. A reduction in body sway was observed in test subjects who used the AR device, signifying an improvement in balance and a decrease in the likelihood of falling. Tests also showed that superimposed movements of the visual reference in 'forward-backward' or "sideways" directions induce respective sway responses, clearly indicating a direction-specific balance integration of the displayed cues. Based on these findings, the scientists concluded that artificially generated visual orientation cues using AR can improve standing balance, reduce sway, and prevent falls.

During testing, the scientists needed to quantify the delay between the motion of the test subject due to body movement and the self-motion correcting pattern motion on the display. A Mikrotron mini2 CMOS camera with a global shutter from SVS-Vistek, Germany, captured the delay by recording test subjects at 1155 frames per second at 1280 × 1024 resolution. Mikrotron Mini GigE cameras were specially developed to record the fastest processes in confined spaces, and have features such as 4,000 megabytes SDRAM internal memory, a compact 63 × 63 × 64.5 millimeter footprint, and the GigE Vision interface. The preprocessing of test data was realized in MATLAB. (Source: SVS-Vistek)

Reference: *M. Albrecht* et al.: Improving balance using augmented visual orientation cues, Res. Square, online 29 August 2023; DOI: 10.21203/rs.3.rs-3289666/v1

www.svs-vistek.com
www.sportwissenschaft.uni-konstanz.de

Improved VR display with high resolution

New approach significantly contributes to the progression of light field displays

Near-eye displays are emerging as the future of portable devices, providing individuals with immersive virtual reality experiences. The primary objectives in developing these displays are to create immersive experiences and ensure visual comfort. While a larger field of view (FOV) enhances immersion in virtual reality, addressing the vergence-accommodation-conflict (VAC) is crucial for comfortable vision. Researchers have explored innovative approaches to tackle these challenges.

A significant breakthrough in near-eye displays is the integration of light field technology.However, earlier light field displays in VR were limited by their small size and low resolution, resulting in constrained viewing angles and screen window effects. The researchers from Innolux Corporation in Taiwan successfully overcame these limitations by utilizing a 3.1-inch 3k3k LC display. Nevertheless, the transition to high-resolution VR LCD displays presented material and process challenges that demanded attention. The research highlights the importance of employing high-resolution liquid crystal displays to address light field resolution issues. The researchers elaborate on strategies to enhance LCD resolution, including aperture and contrast ratios through specialized pixel designs and driving techniques. Additionally, they explore novel applications of light field technology beyond its use in VR displays, namely, in vision correction for VR systems.

"By utilizing light field technology, both vision correction and the expansion of the eyebox are achieved, thereby elevating the overall virtual reality experience and enhancing user comfort," said Yung-Hsun Wu, one of the researchers from Innolux. They investigate the optics of light field virtual reality, demonstrating the creation of elemental image (EI) arrays through a lens array and spatially multiplexed light field optics. This approach generates volumetric virtual images that accurately simulate proper eye accommodation, eliminating the need to address VAC. They focus on a recently-developed Innolux LCD with impressive resolution and pixel density. By introducing a 15-degree tilt between panels, the binocular FOV is expanded, ensuring exceptional angular resolution. The modulation transfer function (MTF) across the image field guarantees the faithful reproduction of high-quality images.

Furthermore, the researchers address visual correction within the realm of light field VR. It introduces a ray tracing-based graphical process – corrected eye box mapping – facilitating the correction of myopia, hyperopia, and astigmatism. This procedure takes into account parameters like spherical power (SPH), cylinder power (CYL), and cylinder axis (AXIS) for comprehensive visual correction. In conclusion, the approach offers a comprehensive exploration of the development of high-resolution light field displays, encompassing advancements in display design, pixel architecture, and vision correction through the integration of light field technology. This research significantly contributes to the progression of light field displays, paving the way for enriched visual experiences within high-resolution VR systems. (Source: SPIE)

A prototype demonstration of high-resolution light field displays for enhanced virtual experiences. (Source: Y.-H. Wu et al., SPIE)

Reference: *Y.-H. Wu* et al.: Enhancing virtual reality with high-resolution light field liquid crystal display technology, J. Opt. Microsys. **3**, 041202 (2023); DOI: 10.1117/1.jom.3.4.041202

www.innolux.com

First-of-its-kind consumer spectroscopy solution

New solution integrates NIR spectroscopy on mobile devices to help improve user health

Announced at Qualcomm Technologies' annual Snapdragon Summit, the solution of Trinamix is the world's first NIR spectrometer integrated in a smartphone reference design, covering the wavelength range from 1 – 3 µm. As a result, the solution is poised to transform personal health and well-being by making previously 'invisible' indicators of health visible – all through consumers' personal mobile devices. It was developed together with two partners: Lumileds, a leading manufacturer of LED light sources, and Viavi Solutions, a manufacturer of optical filters, light shaping optics and handheld industrial spectrometers with extensive experience in the consumer electronics market. The module runs on Qualcomm Technologies' latest Snapdragon 8 Gen 3 reference design.

Skin moisture measurement with consumer spectroscopy solution (Source: Trinamix)

The technology provides non-invasive biomarker measurements on their skin, enabling numerous applications with the potential to revolutionize the way consumers use mobile devices. The smartphone can become a hub of health insights through the proprietary spectroscopy module, smart algorithms, and a user-friendly app. Trinamix Consumer Spectroscopy seamlessly integrates into mobile devices, letting users monitor selected aspects of their health independently and reliably. The comfort, ease-of-use, and safety of non-invasive monitoring could empower individuals to take control of their well-being, whether it be in skin health, nutrition, or other everyday use of biomarkers measurement.

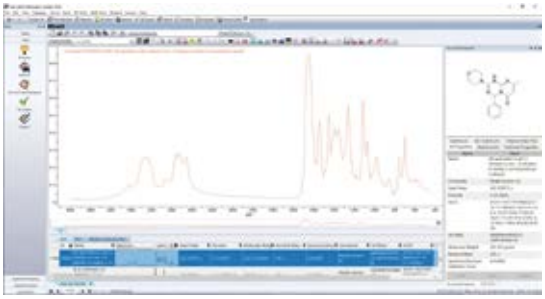
"Think of this technology as a camera that sees what is invisible to the human eye. It integrates right into your mobile device for on-the-go readings, providing an accurate measurement of biomarkers such as hydration levels, allowing users to track vital health indicators. This technology will serve as a foundation for the next generation of apps that will enable consumers to take charge of their well-being and make informed decisions for a healthier lifestyle." said Wilfried Hermes, Trinamix' director consumer electronics North America and Europe.

https://trinamixsensing.com

New database of predicted infrared spectra

Wiley uses the latest AI machine-learning techniques to expand its data and accelerate spectral analysis

The new Wiley Database of Predicted IR Spectra combines over sixty years of expertise in infrared spectroscopy and spectral data curation with the latest machine-learning techniques to significantly expand the number of IR spectral data available for spectral analysis.



Wiley Database of Predicted IR Spectra (Source: Wiley)

With over 250,000 predicted spectra, this new library was created by Wiley Science Solutions using an AI-powered spectrum prediction engine derived from its high-quality Fourier-transform infrared spectroscopy (FTIR) empirical spectral database collection – the largest commercially available. The predicted library can be used along with Wiley's empirical IR spectral reference databases in the spectral analysis of unknown samples and is especially useful for rarer compounds and materials, when a match cannot be found in any empirical database.

This general infrared library covers a broad range of chemical compound classes, including general organics, flavors and fragrances, industrial compounds, androstanes, estrogens and steroids, metabolites, lipids, geochemicals, petrochemicals, biomarkers, drugs, pharmaceuticals, pesticides, toxicology, terpenes and other volatiles found in food, natural products, as well as monomers, PFAS, and more.

Wiley conducted both external and internal studies by subject matter experts (SMEs) to validate results from the predicted database. From these two studies, the SMEs concluded that the new database characterizes unknown spectral functional groups and performs well when searched against using sample spectra. They suggest that the optimal workflow for the predicted library is to use it when an empirical library results in either low hit quality index (HQI) scores, poor matching, or no matches to help users classify and determine the structural characteristics and possible identity of unknown compounds.

While Wiley has among the largest, most extensive commercially available library of high-quality empirical infrared data, the total coverage is significantly smaller than the overall chemical space in use by chemists, life scientists, and materials scientists – i.e., the total number of possible molecules and compounds within a set of elements and rules. Augmenting the empirical coverage within the bounds of a predictive model (the chemical space of the underlying training set) is a strategy to help improve the overall density of coverage within that space for the identification of unknowns, especially for novel compounds.

The database is available for use exclusively with the Wiley KnowItAll software, a comprehensive solution for spectral analysis and management.

www.wiley.com/go/databases

Austria's cluster of excellence for quantum sciences launched

Quantum Science Austria quantA brings together more than sixty research groups in Innsbruck, Vienna, Linz, and Klosterneuburg

Since decades, scientists at the Universities of Innsbruck and Vienna, Vienna University of Technology, JKU Linz, the Institute of Quantum Optics and Quantum Information of the Austrian Academy of Sciences and the Institute of Science and Technology Austria (ISTA) are researching the quantum foundations of space, time and gravity, new paradigms of quantum information and the physics of engineered quantum many-body systems. "Together, we want to push the boundaries of knowledge and thus be a driving force for future innovations," says director of research, Gregor Weihs. "The cluster of excellence offers us the opportunity to explore major questions in quantum research together and to exploit synergies between the working groups. Another important task will be training the future quantum generation. Austria is the best place for studies and research on the fundamentals of quantum physics."

"Not least due to the cooperation of over sixty research groups, this research cluster will also become an international flagship for excellent Austrian research work in one of the key technologies of the future. However, knowledge must also be applied, which is why I welcome the anchoring of knowledge transfer as an important pillar of the clusters of excellence," emphasizes Martin Polaschek, federal minister of education, science and research.

The project tracks funded as part of the cluster include collaborative and inter-institutional research projects in which the core questions of quantum science are researched through targeted collaboration and the joint use of equipment. This strengthens cooperation between the individual research groups throughout Austria in the long term. Twelve of these research projects were already launched in October 2023. In total, around 35 quantum researchers, 12 postdocs and 25 PhD students are working on these first projects at all participating institutions. A second round is about to be announced.

Source: U Innsbruck

l–r: cluster spokesperson Gregor Weihs, science minister Martin Polaschek, university rector Veronika Sexl, and Austrian state secretary for digitalization Florian Tursky

In addition, a separate Austria-wide PhD program is planned with the aim of attracting the best minds and international talents to Austria and promoting them in a targeted manner. A total of up to 70 million euros will be available to around 500 participating scientists over the next ten years.

www.fwf.ac.at/foerdern

Optica Foundation Challenge provides grants for work on a chip-integrated light sensor

Photonic technologies introduce new ways to diagnose menopause and glaucoma

The 2023 Optica Foundation Challenge funds new women's health and vision research. Samantha Grist, The University of British Columbia, Canada, and Fernando Zvietcovich, Pontificia Universidad Catolica del Peru, have proposed two separate light-based techniques to solve for challenges in diagnosing health-related concerns, specifically menopause and glaucoma.

"As healthcare diagnostics advance, new opportunities for non-invasive, light-based techniques continue to emerge," said Alan Willner, chair of the challenge selection committee. "Excitedly, both Dr Samantha Grist and Dr Fernando Zvietcovich are exploring novel, innovative ways of using light to address issues found in current modalities – precisely the kind of exemplary work the Optica Foundation Challenge strives to address."

Each research effort is supported by a 100,000 US dollars grant from the Optica Foundation, and Grist and Zvietcovich will use these funds to advance their research in the following ways:

Grist's silicon PIC approach introduces the potential for quantitative, accurate, data-rich measurements of hormones, with tens to hundreds of biosensors integrated on a single millimeter-scale chip in the future. However, PIC-based biosensor analysis has required costly and bulky systems that limit their applicability in clinical environments – until now. Grist and her team have invented a new sensor architecture that addresses this challenge by applying a tiny, inexpensive laser for readout.

Fernando Zvietcovich, Pontificia Universidad Catolica del Peru, Peru, has proposed the development of a clinical multi-excitation optical coherence elastography system. This system will enable high-resolution structural images of the eye through optical coherence tomography (OCT). At the same time, the system will leverage air and ultrasonic pulses to excite the mechanical waves in the cornea, providing biomechanical information of the eye to help obtain corrected and adjusted intraocular pressure values, thus enabling the detection of normotensive glaucoma (NTG).

For more information and the complete list of 2023 winners, please visit

www.optica.org/foundationchallenge

Strengthening photonics and quantum technologies

Photonics Germany and Photonics21 agreed on an MoU

Source: VDI Technologiezentrum

Photonics Germany and Photonics21 have agreed on a memorandum of understanding to intensify their cooperation and initiate new joint activities. The partners work together on a European level to make the importance of photonics and relating technologies like quantum technologies more visible.

◀ Dr Andreas Ehrhardt (OptecNet Deutschland), Sybille Niemeier (Photonics21), Dr Wenko Süptitz (Spectaris), Dr Lutz Aschke (Photonics21), and Dr Horst Sickinger (OptecNet Deutschland)

It is intended to improve the framework conditions in research and industry, to initiate new funding programs and to define joint measures for Europe-wide public relations.

The European Technology Platform Photonics21 represents the photonics community of industry and research organizations. Photonics Germany is the alliance of OptecNet Deutschland and Spectaris.

www.photonics-germany.de
www.photonics21.org

New board of directors elected

VDMA working group laser and laser systems for material processing fills leadership positions

At the autumn meeting of the 'WG Laser', the chairman and deputy chairman of the board of directors were confirmed and new members were elected.

Dr Hagen Zimer, member of the management board and CEO laser technology at Trumpf, and Nikolas Meyer, head of sales and industry management and member of the executive board at Weil Technology, were newly elected to the board.

Dr Christoph Ullmann was confirmed as chairman of the WG Laser and Dr Stefan Ruppik was confirmed as his deputy.

www.laser.vdma.org

Source: VDMA

Dr Hagen Zimer, Trumpf; Dr Stefan Ruppik, Coherent (vice chairman); Dr Christoph Ullmann, Laserline (chairman); Nikolas Meyer, Weil Technology; Dr Sven Breitung, VDMA

New photonics chairman at Spectaris

Maik Müller takes chairmanship, Dr Christian Korth elected as new board member

Maik Müller (Source: Nynomic)

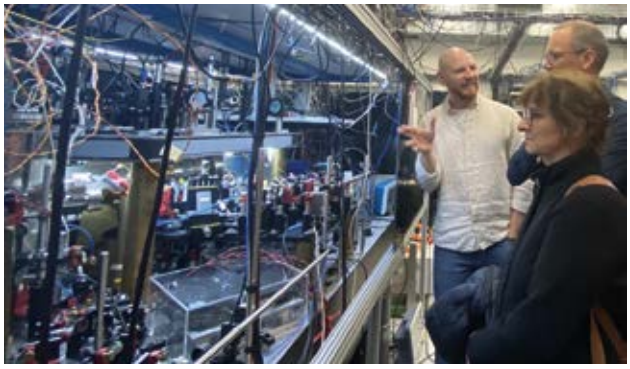
Photonics at Spectaris has a new leader: Maik Müller, CEO of Nynomic, has been elected as the new chairman of the trade association. With 95 percent approval from the members, Müller received the confidence to continue the successful work of his predecessor Dr Bernhard Ohnesorge, managing director of Carl Zeiss Jena.

The new elections had become necessary because Ohnesorge was elected chairman of the Spectaris association in September. In his farewell speech, Ohnesorge praised the past four and a half years of his photonics tenure as a time of a joint departure and emphasized the importance of strategic initiatives such as the expansion of the Photonics Germany association alliance, improved research funding and the recruitment of qualified specialists for German photonics companies. Alongside the election of Maik Müller as the new chairman, Dr Christian Korth from Carl Zeiss Spectroscopy was confirmed as a new member of the photonics board.

www.spectaris.de
www.nynomic.com

Fascinating insights into the Swiss photonics industry

The members of OptecNet Deutschland and Spectaris invited by Swissmem Photonics



Insights into the laboratories at ETH Zürich (Source: Swissmem)

L–r: Dr Andreas Ehrhardt, Dr Horst Sickinger, Dr Wenko Süptitz, Werner Krüsi, and Brigitte Waernier-Gut

Source: Photonics BW

The business initiation trip to Switzerland from November 6th – 8th, 2023, was organized by Swissmem Photonics and supported by Photonics Germany, the alliance of OptecNet Deutschland and Spectaris. The aim of the trip was to further promote joint networking activities, build the foundation for cooperation and joint funding projects.

Brigitte Waernier-Gut, head of the photonics department at Swissmem, welcomed the participants with fascinating insights into the companies and research institutions CSEM SA, Suss Microoptics SA, MPS Micro Precision Systems AG, Victor Kyburz AG, Optotune Switzerland AG, Institute of Electromagnetic Fields (IEF) and Institute for Quantum Electronics at ETH Zürich, IMT Masken und Teilungen AG, Evatec AG, SwissOptic AG, Fisba AG, Vario-Optics AG.

Werner Krüsi (Swissmem Photonics), Dr Andreas Ehrhardt (Photonics BW / OptecNet Deutschland), Dr Horst Sickinger (Bayern Photonics / OptecNet Deutschland) and Dr Wenko Süptitz (Spectaris) discussed the importance of joint funding projects and collaborations between companies and research institutions from Germany and Switzerland. Photonics Germany and Swissmem act as a contact partner for political topics. They support the initiation of cooperation and the acquisition of funding to sustainably strengthening the photonics industry in German-speaking countries and beyond.

OptecNet Deutschland and Spectaris thank all companies and research institutions for the great insights and Swissmem, especially Werner Krüsi and Brigitte Waernier-Gut, for the excellent organization and support.

A new business initiation trip to Germany is planned.

www.photonics-germany.de
www.swissmem.ch

AM experts make a strong addition to the RapidTech 3D advisory board

The VDMA's Additive Manufacturing Working Group will serve as the conceptual sponsor

RapidTech 3D gains professional reinforcement from the industry. AM experts from Schaeffler, Trumpf, BMW, and the VDMA, Germany's mechanical engineering industry association, bring their expertise to the advisory board. Starting in 2024, the Additive Manufacturing Working Group within the VDMA will serve as the conceptual sponsor of the event, which is set to celebrate its 20th anniversary at Messe Erfurt in 2024.

The overarching goal of the partnership with the VDMA Working Group is to further advance the industrialisation of additive manufacturing (AM). This is clear from the Rapid.Tech 3D specialist conference programme, which has been expanded to include the new "AM4industry" session. Organized by the VDMA's AM Working Group, this session is scheduled for day one of the conference (14 May 2024) and will focus on user-oriented lectures on industrial 3D printing along the entire additive process chain.

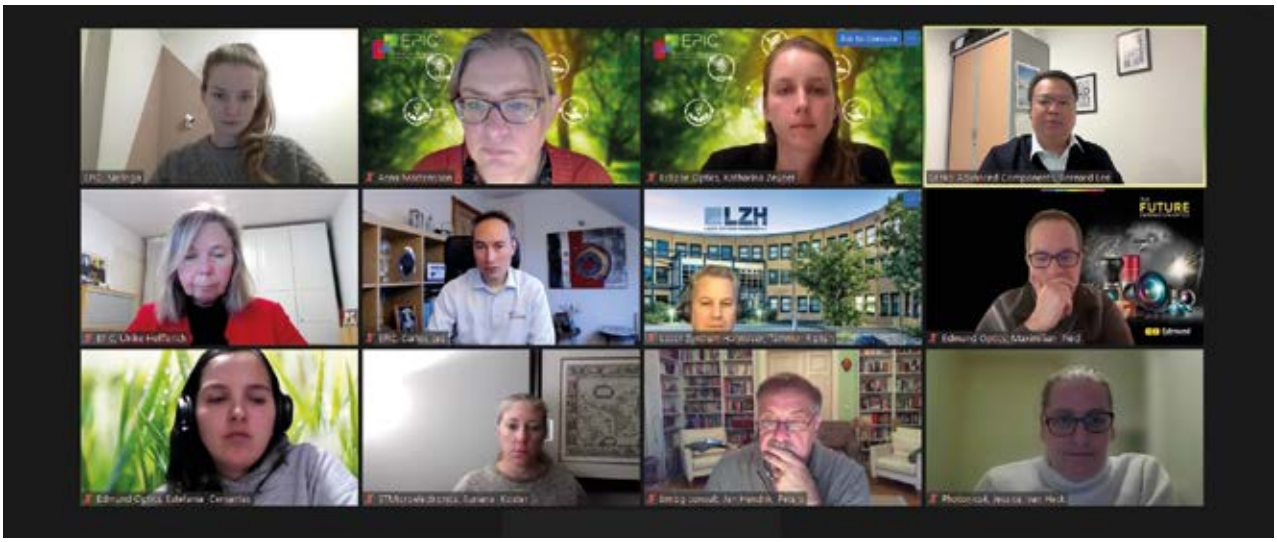
RapidTech 3D advisory board (Source: Messe Erfurt, Christian Seeling)

The new additions to the advisory board are Carsten Merklein, Schaeffler, Dr Tobias Brune, Trumpf; Alexander Jakschik, ULT, and Dr Markus Heering, VDMA.

www.messe-erfurt.de ■ www.vdma.org

HR and Sustainability Workgroups

EPIC members unite to address shared challenges



The Sustainability Workgroup Meeting that was held virtually on 8 December 2023 (Source: EPIC)

EPIC's mission is to enhance the competitiveness of the European Photonics Industry through an international network. This is achieved by organizing 'Technology Meetings' and 'Delegation Trips', enabling EPIC members to network and explore new markets and applications. However, in addressing significant challenges like climate change and talent shortages, a cohesive photonics community is essential.

The sustainability workgroup aims to educate EPIC members on various sustainability topics, emphasizing their implementation's business value. Chaired by Katharina Zeuner of Eclipse Optics and co-chaired by Estefania Cervantes from Edmund Optics and Elizabeth Illy from Hübner Photonics, the workgroup focused on the United Nations Sustainable Development Goals:

- Industry, Innovation, Infrastructure (80 % importance for members)
- Climate action (67 % importance for members)
- Responsible consumption and production (60 % importance for members)
- Affordable and clean energy (53 % importance for members)

The workgroup addressing human resources challenges, which is chaired by Ilse de Graaf from Smart Photonics, agreed that a collaborative approach emerged as a potential solution, as the talent competition extends beyond photonics to other industries. By drawing from a global pool of candidates, photonics companies could collectively work together to attract talent. This is the purpose of the 'Career Booth' initiative showcased at some fairs, aiming to display job vacancies and provide opportunities for in-person meetings between job seekers and EPIC members during the shows. The common challenges faced include hiring from abroad, competing with big players, understanding Generation Z, and promoting photonics as a career option.

Check the QR Code to see all the scheduled workgroups for 2024:

www.epic-assoc.com

Upcoming EPIC events:

- 19 February 2024 / 15:00 – 17:00 CET
  EPIC Online Technology Meeting on New Developments for Laser Welding
- 20 – 23 February 2024
  EPIC Members Delegation to Abu Dhabi, UAE
  Abu Dhabi, United Arab Emirates
- 26 February 2024 / 15:00 – 17:00 CET
  EPIC Online Technology Meeting on Photonics for Automotive Lighting
- 4 March 2024 / 15:00 – 17:00 CET
  EPIC Online Technology Meeting on Photonics for Earth Observation and Monitoring
- 6 March 2024 / 15:00 – 17:00 CET
  EPIC Online Technology Meeting on Photonics with Quantum Materials
- 18 March 2024 / 15:00 – 17:00 CET
  EPIC Online Technology Meeting on Quantum Computers
- 27 March 2024 / 06:30 – 09:00 PST
  EPIC Members Run at OFC
  San Diego, CA, USA
- 27 March 2024 / 18:00 – 22:00 PST
  EPIC VIP Networking Reception at OFC
  San Diego, CA, USA
- 8 April 2024 / 15:00 – 17:00 CEST
  EPIC Online Technology Meeting on Photonics Technologies to Improve Pharma Processes
- 11 April 2024 / 15:00 – 16:00 CEST
  EPIC HR Workgroup meeting
- 12 April 2024 / 15:00 – 16:00 CEST
  EPIC Sustainability Workgroup Meeting

For the list of all events, visit:

www.epic-assoc.com/epic-events

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"Give customers more accessible data from production"

Christian Raith, CEO of IMM Photonics, talks to EPIC's Antonio Castelo

Source all images: IMM Photonics

The head of the family-owned German company tells the story of running a producer and distributor of optical and optoelectronic components and laser modules for a wide range of technology sectors.

What's the background to your appointment as CEO?

In 2010, after completing a Diplom Ingenieur (FH) at the Hochschule München University of Applied Sciences, I went to work for the family business, IMM Photonics, which my parents had founded in 1992. I initially worked as a development engineer, but quickly realized that I had neither the aptitude nor inclination for engineering. What I found out was that I liked talking and communicating with people and that with my scientific background, I was able to understand how our technology could help to solve customers' problems. As a result, after six months, I moved into sales, and in 2015, I became head of sales and marketing.

In 2016, as my parents were nearing retirement, they sat down with me and asked me if I was interested in running the business. I wasn't put under any pressure, it was simply the case that if I agreed, they would do everything to help, and if I said no, they would have to start making plans to sell the company. I enjoyed my work, and although I was still in my late twenties, I gratefully accepted the challenge, and from then on, I began to prepare for my future role as CEO. This involved learning about finance, IT and HR, which were my mother's responsibility, and working alongside my father who was in charge of product development, R&D, and manufacturing. When my mother retired in 2020, I became co-managing director with my father, and when he retired in 2023, I assumed sole responsibility for the company.

How has the company developed?

When my parents started in 1992, my father's original plan was to make measuring equipment for the medical market. But this didn't work out, so he moved into the distribution of laser diodes, lenses and other optical components. This was the base for growing our customers base, learning about the customers' needs and moving fast into building our own products. We mainly produce laser diode modules, laser collimators, fiber optics, fiber couplings and we have our own visual fault locator. More recently, we've started making systems, which is just a higher level of integration – not just a laser collimator or module or fiber coupling – but also the surrounding components, so more electronics, some software and so on. And nearly everything is on custom design basis.

▲ Christian Raith, chief executive officer of IMM Photonics

We now have a workforce of around sixty. Just over twenty people are at our headquarters in Unterschleissheim, close to Munich, where we do product development, R&D, sales, order processing and strategic purchasing and have our marketing, IT and HR departments. And we have another 35 employees at our production site in Teisnach, close to the Deggendorf Institute of Technology, which gives us access to the latest findings in measuring technology, production engineering and process development. We work closely with the companies on the technology campus to obtain an optimal transfer of knowledge, which allows us to make use of a wide range of synergies.

We have distributors in the UK, the US, China, Japan, and Korea, but most of our business is in Europe and North America. Our main markets are laser and optoelectronic systems for industrial sensing, mold detection, gas detection and material processing, optical technologies to support medical research, analytics and therapy, and fiber optics for fast optical data transfer, fiber optic installation and testing.

How did you come to transition from a distributor to making your own products?
It started with requests from customers. Many customers who want to use lasers in their systems are not really familiar with building collimators, fiber coupling, or whatever, or they cannot do it because they don't have a cleanroom for the optics. Originally, my parents sold laser diodes and lenses, then customers began to ask us to assemble them, and that's how the collimator business started. They then asked us to do the electronics, and that's how the modules came about. Some time later, we learned about their needs for fiber optics and fiber coupling, so we transitioned from selling parts like the collimators to assembling complex systems. To make these modules and systems, we buy in optics, but the electronics and mechanics are designed by us.

How do you manage the competition from Asia?
We don't have much business left with standard products because of competition from Asia particularly China. In recent years, they've improved a lot in reliability and quality, and it's not easy for us to compete on price. For this reason, we focus on custom design products.

What were your main challenges when you became sole chief executive officer?
It was actually quite a smooth transition. We had been working on the whole process for five years before I took over. One of the things we did was to establish a secondary level of management comprising a CTO, CFO, COO, CSO. This has worked very well because we got the right people. The CFO was recruited just before my mother retired and the COO and CTO positions were filled by longtime employees.

What challenges do you see for the future?
In general, we want to grow in the area where we are currently located. What we see for the future is the need for more and more complex devices and we focus on these types of products. To this end, we are reorganizing our workshop in order to implement a new production strategy with a focus on digitalization. The aim is to give customers more accessible data from production. The more complex a system gets, the greater the number of potential problems and the harder it is to find them. It's like in physics – the deeper you look into something, the more complex it gets, but it's easier to understand if you have the data. A second challenge is that there are a lot of companies, even within Germany, who don't know us because we usually work under nondisclosure agreements and we are not allowed to promote our solutions. We need to reach out to these potential customers and find out what their needs are in depth. For this reason, we regularly attend EPIC events where we can start talking to potential customers – bearing in mind that in the industrial sector, particularly for medical devises, it can take anything up to five years for business to develop.

Laser diode module ilumVISION – HK Laser

But perhaps the biggest challenge for us is that as we grow, we will need to be more flexible and able to adjust quickly. It's easy for a start-up to adjust, but the bigger a company gets, the tougher it is to be flexible.

What's your advice for the next generation of entrepreneurs thinking about taking over the family business?
To the children, I'd say that taking over a family business has to be something you clearly want. If you're in any doubt, don't do it; but if you feel comfortable with the decision, go for it. And don't be afraid of making mistakes because you will learn from them.

To the parents, it's very important to trust in your children. What I've seen many times, fortunately not in my case, are parents hovering too long in the background reluctant to relinquish control. At some point, you will have to say, okay, the company is yours now, go for it, and it's better to do this sooner rather than later.

Company

IMM Photonics

For more than thirty years, IMM Photonics has provided trust-based and successful support to customers from a range of technological fields with the production of innovative components and modules. Its standard optical and optoelectronic products are produced in-house at our two German business locations and by selected partner manufacturers.
High-quality standard products include laser diode modules and collimators, fiber optic components, fiber fault locators and UV light sources for UV curing. All products can be enhanced and adapted to the customer's specific needs.

www.imm-photonics.de

Dr Antonio Castelo-Porta

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Quantum technology: just a hype, or is it the future?

Toptica Eagleyard's Claus Heitmann, Michael Kneier, and Björn Globisch share their key insights

Source all images: Toptica Eagleyard

Everyone is talking about quantum technology (QT) – but what does this buzzword, with its origins in the photonics industry, actually mean in practice? As an experienced company in the QT sector, Toptica Eagleyard shares some key insights on its pivotal role in the industry in an interview, and reports on what QT has to do with the 'valley of tears' and 'coming home'.

In October 2023, Claus Heitmann (CEO), Michael Kneier (VP sales and marketing) and Dr Björn Globisch (head of R&D) spent six exciting days on the 'Quantum Berlin goes USA' delegation trip to Washington, organized by Berlin Partner for Business and Technology, which focused exclusively on quantum technology. The event was accompanied by State Secretary Michael Biel of the Berlin Senate Department for Economics, Energy and Public Enterprises. As a management team, all three have gained a great deal of impressions in various areas of quantum technology during this trip and are faced with both application-specific challenges on the customer side and development-specific issues, as Toptica Eagleyard has been developing laser modules for innovative applications for many years and is now successfully entering the QT segment. Under the motto 'thinking beyond' the company works in partnership with innovation leaders to jointly realize visions in the QT field with highly integrated laser diodes and expert knowledge.

Which visit did you find the most surprising during the delegation trip? What impressed you the most?

Heitmann: We had an extremely exciting delegation trip organized by Berlin Partner for Business and Technology, during which we visited Nasa, IonQ, the Quantum World Congress, the Quantum Catalyzer, the National Institute for Standards and Technology NIST, and the German Embassy in Washington DC – there really were a lot of highlights and new impressions. The discussions with the managing director of the Representative of German Industry and Trade, Dr Christoph Schemionek, and the German Aerospace Center's Washington Office, Marc Jochemich, are particularly memorable for me.

Globisch: What surprised me the most was my visit to the Quantum World Congress (QWC). There were a lot of overview presentations and only a few technical presentations. From my point

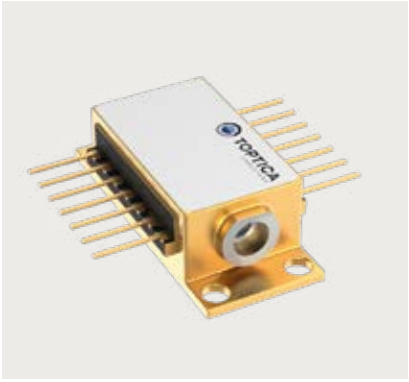
▲ l–r: Claus Heitmann, Dr Björn Globisch, and Michael Kneier

of view, the QWC's target group was primarily a political audience. That did surprise me a bit. I would actually have expected more of a technical focus. What impressed me the most was the visit to IonQ and, in particular, the maturity of the trapped-ion quantum computers. IonQ has a very elaborate product and business strategy, although the applications are not yet clear.

Kneier: That was actually what I found the most surprising at the congress in connection with the visit to IonQ. They have a very tight timetable and they work on their technology roadmap under great pressure. At the same time, they still look for use cases and have approached the technology community very openly. I am curious to see what success stories will develop from this 'business-science clash' over the next few years. I also found it very impressive how many acquainted customers we are represented with under the heading of quantum technology. This was a welcome confirmation of how well we are already positioned in this market. Some customer visits, such as to Nasa or NIST, which were organized as part of the delegation trip, felt a bit like 'coming home.'

Has the trip changed how you think about the QT market and its future?

Heitmann: Yes. For me, QT is a very oversized umbrella term that is still relatively 'sticky.' The desired and comprehensible granularity behind the term QT is still missing. However, I can see the enormous potential and the need to integrate into this QT market. We have this opportunity with our products, and this was clearly demonstrated by the IonQ visit, for example – people are already talking about miniaturization and scaling and this fits in perfectly with the strategic direction of Toptica Eagleyard.



miniECL

miniTA

What is your favorite QT application and why?

Heitmann: My favorite QT applications are applications where I can also see or recognize a 'world improvement effect,' e.g., in the medical field – in other words, an application with real tangible added value. So yes, it could be a quantum computer, but it is less tangible for me. QT applications and applications in the field of QT sensing are the highlight for me – very valuable treatments on patients are made possible by QT sensing, which motivates me.

Kneier: My favorite applications are those where our products are closest to the market or closest to the application: in the field of sensor technology, for example, these are particle sensors, exoskeleton control, magnetometers, where we are already the furthest along with our customers.

Which QT applications do you think will be first on the market?

Globisch: I think the first application that already exists in principle today is QKD, i.e. quantum key distribution. It will be the first to make it, simply because there is a state security aspect behind it. In my opinion, this will be the first application to go to market, although the market is small.

Heitmann: But of all the QT applications, this huge range of applications, sensing is simply the furthest along in my view.

Kneier: Sensing is the most visible area for us, because this is where laser diodes can make the most of their advantages: small form factor, efficiency, precision.

What is the biggest challenge in the QT market at the moment?

Kneier: This is currently mainly on our customer side. I heard this very clearly in the corridors at the Quantum World Congress. Many players are still looking for the real 'major app' in some places. Who really benefits from this to such an extent that business cases can be derived from it? And we at Eagleyard are already pretty well prepared for this with our roadmap for the scalability of energy-efficient laser diode components.

Globisch: I believe that the term quantum technology has created very high expectations, and we now have to show that we can fulfill them – at least in part. IonQ has also confirmed this with its strategy. It can (and must) now be shown that quantum computers can be built and that interested users can also use them. All QT companies that are close to the application must now work towards demonstrating a user benefit.

Kneier: One major challenge, for example, is that the US government appears to have a clear expectation, particularly from the American QT community, that a clear application and benefit of quantum technology must be found within the next five years if funding on the current scale is to be provided in the longer term. I am not sure if everyone has internalized this yet. It is a playing field where you have to show what it is good for in a commercially convincing way within a given time frame.

Heitmann: It is a bit like a race. This race is the challenge. Who is positioning themselves in this major QT event and who

Company

Toptica Eagleyard

Based in Berlin, Germany, the company is a leading supplier of high-power laser diodes in the wavelength range from 630 to 1120 nanometers. The products used around the globe combine maximum performance, maximum service life and excellent beam quality, making them particularly suitable for industrial, medical, scientific, and aerospace applications. Founded in 2002 as a spin-off from the Ferdinand-Braun-Institute (FBH), it now plays a leading role with its GaAs-based laser diode portfolio. With its expertise, experience and know-how, market-ready products are developed from research results and sold worldwide either directly or via partners. The company has been part of the TOPTICA Group since 2013.

www.toptica-eagleyard.com

really has applications at the end and can also show that it is not just a research development, but that it really can be reproduced and manufactured. That is extremely important so that it does not end up becoming an umbrella term for something that everyone will remember as funny in ten years' time.

Imagine it is the year 2033, what does the QT world look like then? And what about in 2043?

Kneier: In ten years' time, we will see QT applications in some fields, I think so. Not in the breadth or to the extent that it is currently being hyped. But there will be segments where QT has its uses. I particularly believe in the field of sensor technology – QT can bring significant advantages for a wide range of measurement tasks and accuracies. We have just received confirmation during a customer visit to Harvard that our miniECLs and miniTAs will "dominate the Rydberg community" over the next five years.

Heitmann: In ten years' time, we will be anchored in the market with even more innovative products and greater scalability, especially in the field of QT sensing. It is difficult to predict in twenty years' time, but I can see that development cycles are getting shorter, and that genuine innovations are always a particular challenge.

Globisch: I believe that we are going through the normal hype cycle with QT, as with all other technologies. We are currently experiencing an exponential rise, and I believe this will continue for another three to five years. This will certainly be followed by a noticeable cooling down. On the one hand, because state subsidies will decrease significantly and, on the other, because private investors will also invest much more conservatively in the technology.

At this point, the applications that really have market potential will crystallize. The first real QT applications will certainly be available in 2033. In computing, it will be quantum computers that have a real advantage over classical computers for individual, relevant problems in practice, although quantum computers will continue to be large and expensive.

In twenty years, the 'valley of tears' should be overcome, i.e. individual initial applications with higher quantities will be addressed, the technology will be further developed for these applications and miniaturized in such a way that the entry hurdle for new applications is low. And so, in twenty years, we should actually have a quantum business.

Heitmann: You always think that there are parallels to the eras of Data and Telecommunications. That were also twenty/thirty years. Look at where we were thirty years ago in the data and telecoms world and everyone jumped on the bandwagon. Is the QT world also just a bandwagon that everyone jumps on and then you somehow realize in ten or twenty years that everything turned out differently than we thought? I hope not.

Which QT applications do you think will have the greatest impact on people's everyday lives?

Kneier: At the moment, the control of exoskeletons is also supported by human-brain interface applications. So I can imagine a lot of potential in the field of prosthetics. If things continue to develop as they are at the moment, I expect this to be of great benefit to people's everyday lives.

Heitmann: I see the area of sensor technology in the same way. I see the greatest tangible benefit for me in the medical sector. So, if you think about hospital beds, where epileptic seizures, for example, can be diagnosed more quickly.

Kneier: Stroke prevention, for example, as a 'consumer good' on every ambulance for diagnostics.

Heitmann: And we are working with many customers and start-up ideas that are already living these innovative approaches today.

Globisch: Yes, I think it is more for applications in the medical field. Everything else does not have that much influence on our day-to-day lives.

What is Toptica Eagleyard working on in the QT area, and what are the current challenges?

Globisch: In principle, a laser with a small linewidth and high output power that is as miniaturized as possible is important for almost every QT application. And that is exactly what we are working on at Eagleyard. We also specifically select the attractive QT wavelengths and then develop lasers with a small linewidth and high output power, such as the miniECL in combination with a miniTA or a DFB laser with miniTA or, thinking a little further into the future: PIC lasers, which promise even smaller linewidths and can possibly even be combined with a TA, which then provides the necessary output power.

Kneier: And all of this is based on an industrial platform for laser diode components that is scalable.

What is your biggest QT challenge personally in your role at Eagleyard?

Heitmann: Developing the right roadmaps today that consider and reflect this great decade in the best possible way. Focused on products that appeal to a wide range of applications. And to find talented people who are able to develop and build such products not from a research perspective, but with an industrial approach, so that they can be reproduced and implemented in large quantities.

Kneier: In our dynamic business environment, it is challenging in terms of sales to simultaneously serve an outstandingly innovative segment with QT in line with the market, in order to help shape the resulting opportunities in the long term. The challenge for our customers is to distinguish the successful start-ups from the others at an early stage.

Globisch: For me, it is about finding the right partners who can support precisely this approach that Claus has just mentioned. So, we cannot do everything ourselves in technology. We are dependent on partners who do electronics development and passive chip development. You have to find those who really think in terms of industry and do not just want to take the research money with them, in order to stay alive. On our side, the challenge is to develop the right platforms with which we are positioned modularly, in order to be able to cover the entire scope of diversity offered by quantum technology as efficiently as possible, so that we do not have to develop something new for every application.

Thank you very much for the interesting interview and the exciting insights!

*

Photos and text provided by Toptica Eagleyard.

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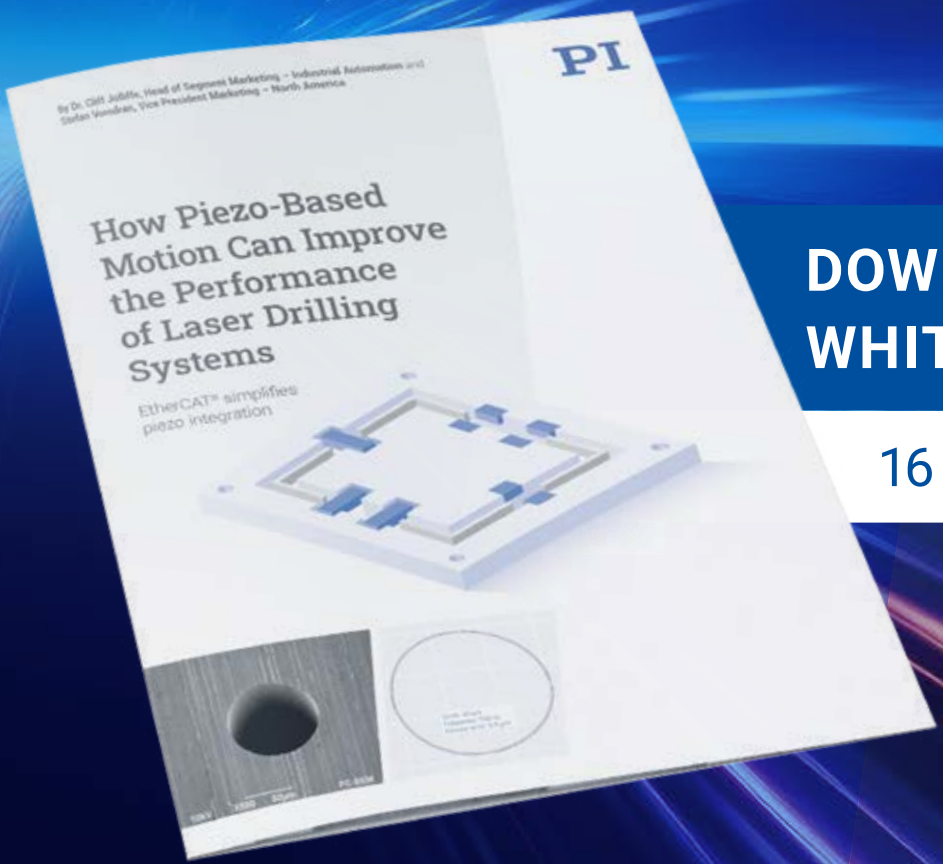

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Scalable quantum simulations on a photonic chip

System using synthetic dimensions could be used to help explain complex natural phenomena

Scientists have made an important step toward developing computers advanced enough to simulate complex natural phenomena at the quantum level. While these types of simulations are too cumbersome or outright impossible for classical computers to handle, photonics-based quantum computing systems could provide a solution. A team of researchers from the University of Rochester's Hajim School of Engineering & Applied Sciences developed a new chip-scale optical quantum simulator that could help make such a system feasible.

Quing Lin's team ran the simulations in a synthetic space that mimics the physical world by controlling the frequency of quantum entangled photons as time elapses. This approach differs from the traditional photonics-based computing methods in which the paths of photons are controlled, and also drastically reduces the physical footprint and resource requirements. "For the first time, we have been able to produce a quantum-correlated synthetic crystal," says Lin. "Our approach significantly extends the dimensions of the synthetic space, enabling us to perform simulations of several quantum-scale phenomena such as random walks of quantum entangled photons."

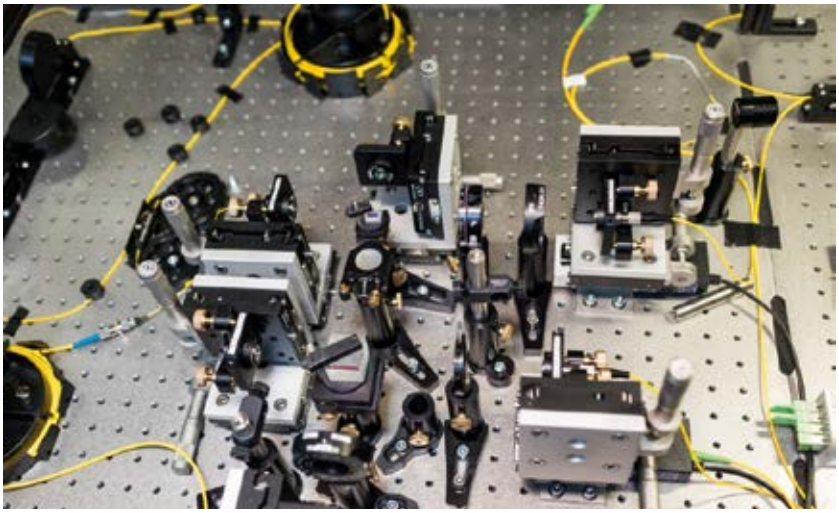
The researchers say that this system can serve as a basis for more intricate simulations in the future. "Though the systems being simulated are well understood, this proof-of-principle experiment demonstrates the power of this new approach for scaling up to more complex simulations and computation tasks, something we are very excited to investigate in the future," says Usman Javid. (Source: U. Rochester)

Reference: *U. A. Javid* et al.: Chip-scale simulations in a quantum-correlated synthetic space, Nat. Phot., online 22 June 2023; DOI: 10.1038/s41566-023-01236-7

www.hajim.rochester.edu/optics

A linear path to efficient quantum technologies

Bell state measurements open up new perspectives for photonic quantum technologies



The experimental setup consists exclusively of linear components, such as mirrors, beam splitters and waveplates, which ensures scalability (Source: La Rici Photogr.)

The group of Stefanie Barz at the University of Stuttgart and the Center for Integrated Quantum Science and Technology (IQST) has improved the efficiency of an essential building block of many quantum devices beyond a seemingly inherent limit. Doctoral researchers Matthias Bayerbach and Simone D'Aurelio carried out Bell state measurements in which they achieved a success rate of 57.9 %. This unmatched efficiency was made possible by using two additional photons in tandem with the entangled photon pair. It has been known in theory that such auxiliary photons offer a way to perform Bell state measurements with an efficiency beyond 50 %. However, experimental realization has remained elusive.

One reason for this is that sophisticated detectors are needed that resolve the number of photons impinging on them. Bayerbach and D'Aurelio overcame this challenge by using 48 single-photon detectors operating in near-perfect synchrony to detect the precise states of up to four photons arriving at the detector array. With this capability, the team was able to detect distinct photon number distributions for each Bell state – albeit with some overlap for the two originally indistinguishable states, which is why the efficiency could not exceed 62.5 %, even in theory. But the 50 % barrier has been surpassed. Furthermore, the probability of success can, in principle, be arbitrarily close to 100 %, at the cost of having to add a higher number of ancilla photons.

Even the most sophisticated experiment is plagued by imperfections, and this reality has to be taken into account when analyzing the data and predicting how the technique would work for larger systems. The Stuttgart researchers therefore teamed up with Peter van Loock, a theorist at the Johannes Gutenberg University in Mainz and one of the architects of the ancilla-assisted Bell state measurement scheme.

Although the increase in efficiency from 50 to 57.9 % may seem modest, it provides an enormous advantage in scenarios where a number of sequential measurements need to be made, for example in long-distance quantum communication. For such upscaling, it is essential that the linear-optics platform has a relatively low instrumental complexity compared to other approaches.

Reference: *M. J. Bayerbach* et al.: Bell-state measurement exceeding 50% success probability with linear optics, Sci. Adv. **9**, adf4080 (2023); DOI: 10.1126/sciadv.adf4080

www.iqst.org

Towards the quantum internet

The future of the Web lies in quantum communication

With its immense computing power, quantum communication is set to become the backbone of the next-generation internet. In the German state of Saarland, a test track is now operational between the Universität des Saarlandes (UdS) and the Hochschule für Technik und Wirtschaft des Saarlandes, Saarbrücken, with dimensions that can simulate real life applications. The groups of Jürgen Eschner and Christoph Becher at the UdS are using single trapped ions and single photons to develop and study the basic building blocks for future quantum networks.

An essential aspect of these networks is the ability to distribute entanglement between distant nodes using photonic channels, such as free-space transmission or fiber networks. In this joint experiment, quantum memories based on single trapped Ca+ ions and nitrogen vacancy (NV) centers in diamond are controlled and manipulated in two separate laboratories connected by a 15 km fiber optic link, provided by a local telecom company.

Frequency-comb stabilized laser system for Saarland University, Prof Esch group (Source: Toptica)

The trapped Ca+ ions and tin-vacancy (SnV) centers are excited to a short-lived upper state, emitting a single photon as they decay. This so-called A-type transition allows the spin state of the atom to be entangled with the polarization or emission time of the single photon. The generated photons have wavelengths of 854 nm (Ca+) and 619 nm (SnV), respectively.

Toptica has provided most of the lasers for trapping, cooling and interrogating the atoms, as well as an optical parametric oscillator for the quantum frequency conversion (QFC). Two DFC frequency combs synchronize the experiments, while two transfer lasers at telecom wavelengths and active fiber noise cancellation ensure low-noise photon transmission.

www.toptica.com

Generating single photons and encoding information

A step toward using single photons in quantum communication and information processing

A new approach to quantum light emitters generates a stream of circularly polarized single photons, that may be useful for a range of quantum information and communication applications. A Los Alamos National Laboratory team stacked two different, atomically thin materials to realize this chiral quantum light source. "Our research shows that it is possible for a monolayer semiconductor to emit circularly polarized light without the help of an external magnetic field," said Han Htoon. "This effect has only been achieved before with high magnetic fields created by bulky superconducting magnets, by coupling quantum emitters to very complex nanoscale photonics structures or by injecting spin-polarized carriers into quantum emitters. Our proximity-effect approach has the advantage of low-cost fabrication and reliability."

The polarization state is a means of encoding the photon, so this achievement is an important step in the direction of quantum cryptography or quantum communication. "With a source to generate a stream of single photons and also introduce polarization, we have essentially combined two devices in one," Htoon said. The research team worked at the Center for Integrated Nanotechnologies to stack a single-molecule thick layer of tungsten diselenide semiconductor onto a thicker layer of nickel phosphorus trisulfide magnetic semiconductor. Postdoc Xiangzhi Li used atomic force microscopy to create a series of nanometer-scale indentations on the thin stack of materials. The indentations are approximately 400 nanometers in diameter.

The indentations created by the atomic microscopy tool proved useful for two effects when a laser was focused on the stack of materials. First, the indentation forms a well, or depression, in the potential energy landscape. Electrons of the tungsten diselenide monolayer fall into the depression. That stimulates the emission of a stream of single photons from the well. The nanoindentation also disrupts the typical magnetic properties of the underlying nickel phosphorus trisulfide crystal, creating a local magnetic moment pointing up out of the materials. That magnetic moment circularly polarizes the emitted photons. (Source: LANL)

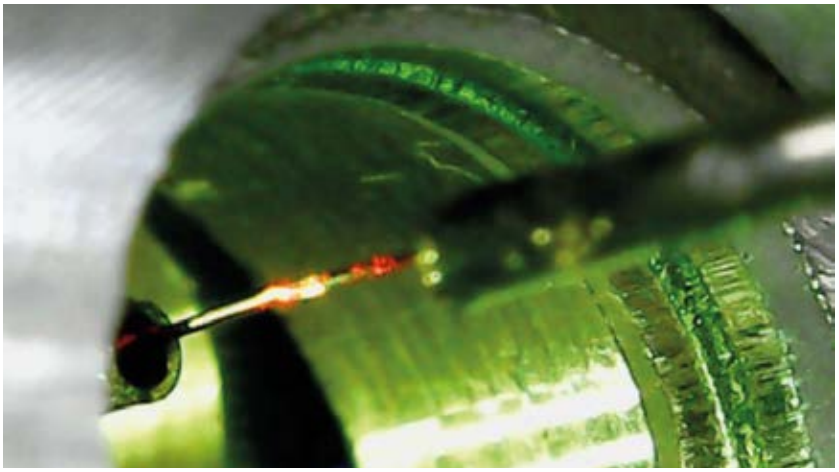
Reference: *X. Li* et al.: Proximity-induced chiral quantum light generation in strain-engineered $WSe_2/NiPS_3$ heterostructures, Nat. Mat., online 17 August 2023; DOI: 10.1038/s41563-023-01645-7

https://cint.lanl.gov

A new platform for quantum information processing

Single rare-earth ions detected in a nanoparticle that has been coupled to a fiber microcavity

Scientists are searching for the optimal qubit platform that can perform operations more efficiently, accurately and as fast as possible. With the additional goal of interfacing a quantum processing system with a quantum network, a system able to generate entanglement between long-lived matter qubits and photons is the most desirable, allowing for a low-loss and fast interface between the nodes of the future quantum internet. Now, an international team of researchers have shown how single rare-earth ions can be addressed and detected in an ensemble of atoms within a nanoparticle that has been coupled to a fiber-microcavity, which enhances efficient light-matter interaction.



Source: E. Beattie, ICFO

A close up of the fiber approaching the mirror to form the cavity

Qubits realized in solid-state spins have attracted a lot of attention in recent years. The qubits are naturally trapped in the matrix of the solid, such as diamond or silicate crystals, and if placed close to each other they can be made to interact, creating qubit-qubit gates. Many can also be read out through the emission of a photon, enabling spin-photon entanglement to be generated.

However, these requirements are pushing the experiment in different directions. Finding single qubits in a solid requires a matrix with a low concentration of spins to make sure that they are all spectrally separated and can then be addressed individually. At the same time, such a low density would increase the average distance between spins, resulting in a low interaction between the ions, which is the necessary tool for qubit-qubit gates. In recent years, researchers have found that rare-earth ion-doped crystals provide a robust system and reliable platform for light-matter interaction.

Now ICFO researchers Chetan Deshmukh, Eduardo Beattie, Bernardo Casabone, and Samuele Grandi, led by Hugues de Riedmatten, in collaboration with Diana Serrano, Alban Ferrier and Philippe Goldner from Institute de Recherche de Chimie de Paris, and David Hunger from Karlsruher Institute für Technologie, have come up with an ingenious way of doing just this. In their experiment, they used erbium ions emitting single photons at telecommunication wavelength and packed into a volume two orders of magnitude smaller than in previous realizations. (Source: ICFO)

Reference: *C. Deshmukh* et al.: Detection of single ions in a nanoparticle coupled to a fiber cavity, Optica **10**, 1339 (2023); DOI: 10.1364/optica.491692

www.icfo.eu

Pearl Chair for novel quantum computing project

Florian Kaiser to receive €4M in funding for the next five years through Luxembourg's National Research Fund

Dr Florian Kaiser (Source: LIST)

Dr Florian Kaiser, who leads the Quantum Materials group at the Luxembourg Institute of Science and Technology (LIST), has been awarded the FNR Pearl Chair by the Luxembourg National Research Fund (FNR) for his project focused on enhancing the performance of quantum computers named Advanced Quantum Technologies with Silicon Carbide (AQuaTSiC). The project is set to receive four million euros in funding for the next five years via the FNR Pearl Programme, which offers competitive grants to attract leading researchers in strategic research fields to Luxembourg.

Today's quantum computers only involve single units, similar to early traditional computers. Scaling up qubit numbers beyond a few dozen is difficult due to an increased sensitivity against decoherence. This means that quantum computer performance is generally based on compromises, which challenges the demonstration of a quantum advantage. Just 53 quantum bits can encode the equivalent of 1 Petabyte of data, which is an enormous volume of information. Moreover, quantum computers excel at processing substantial data sets in parallel, offering the potential to significantly accelerate data-intensive tasks.

"However, the current state of quantum technology faces challenges in achieving the necessary hardware enhancements to effectively support these applications," says Kaiser. "In this context, AQuaTSiC aims to develop a unique quantum computing platform using the industry leading 3rd generation semiconductor, silicon carbide. This material is already used in electric cars, and our goal is to benefit from these technological advances to develop better performing materials for quantum computing."

The goal of AQuaTSiC is to maximize the number of qubits by connecting multiple systems. Contrary to standard approaches, "our strategy emphasizes the creation of small qubit registers of superior quality," adds Kaiser. The project, which is slated to commence at the beginning of 2024, aims to integrate two small-scale quantum computing units on a photonic chip, akin to the way processors work on modern computer chips. This innovative approach allows for efficient communication between quantum computing units.

To address the challenge of connecting quantum computers using photons instead of electrical wires, "we will employ silicon carbide waveguides in which photons travel between the quantum components," explains Kaiser.

One of the key differentiators of the project is its focus on scalability. Unlike other specialized quantum computing systems that require custom engineering for each chip, the fabrication of quantum chips can be easily scaled up here through the industrial partners.

www.list.lu

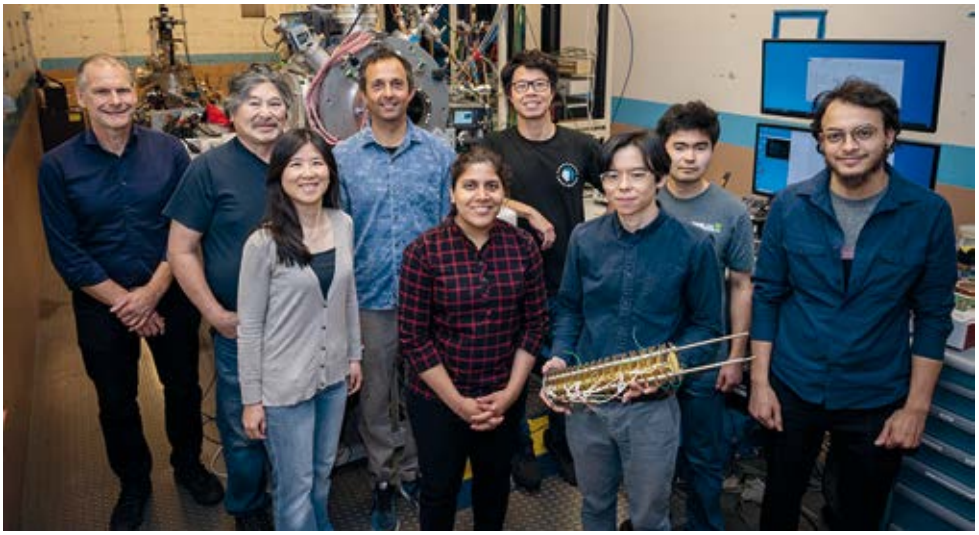
New emitters for a quantum internet

Improved understanding of how light-emitting defects form and behave

To produce and manipulate individual photons, scientists are turning to quantum light emitters, the color centers. These atomic-scale defects in semiconductor materials can emit single photons of fixed wavelength or color and allow photons to interact with electron spin properties in controlled ways. A team of researchers has recently demonstrated a more effective technique for creating quantum emitters using pulsed ion beams, deepening our understanding of how quantum emitters are formed. The work was led by Berkeley Lab researchers Thomas Schenkel, Liang Tan, and Boubacar Kanté. The results are part of a larger effort by the team to identify the best quantum defect emitters for processing and transporting quantum information and to produce them with precision.

In this work, the team targeted the fabrication of a specific type of color center in silicon comprising two substitutional carbon atoms and a slightly dislodged silicon atom. The conventional method of producing the defects is to hit the silicon with a continuous beam of high-energy ions, however, the researchers discovered that a pulsed ion beam is significantly more efficient, producing many more of the desired color centers.

The team characterized the color centers at cryogenic temperatures using highly sensitive near-infrared detectors to probe their optical signals. They found that the intensity of the ion beam used to create the color centers changed the optical properties of the photons they emitted. Large-scale computer simulations on the Perlmutter system at the National Energy Research Scientific Computing Center (NERSC) provided further insight, revealing that the wavelength of emitted photons is sensitive to strain in the crystal lattice.



L–r: Thomas Schenkel, Takeshi Katayanagi, Qing Ji, Arun Persaud, Kaushalya Jhuria, Wei Liu, Liang Tan, Yertay Zhiyenbayev, and Walid Redjem (Source: T. Swift, Berkeley Lab)

The findings also suggest a new application for quantum emitter color centers as sensors for radiation. "It opens new directions," said Liang Tan, a staff scientist at Berkeley Lab's Molecular Foundry.

Ongoing work includes generating a database of color centers predicted to exist in silicon, using computer simulations to identify those best suited to quantum computing and networking applications, and refining fabrication techniques to gain deterministic control over creating individual color centers.

"We're working towards a new paradigm of qubits by design," said UCB professor Boubacar Kanté. "Can we reliably make a color center that operates in the telecom band, has sufficient brightness, is not too hard to make, has a memory, etcetera? We're engaged in that quest and have demonstrated some exciting progress." Berkely Lab division director Cameron Geddes added, "The new pathways to forming color centers using intense beams uncovered in this work are an exciting application of high energy density conditions and plasma science to improving technologies for quantum information science." (Source: LBL)

Reference: *W. Liu* et al.: Quantum Emitter Formation Dynamics and Probing of Radiation-Induced Atomic Disorder in Silicon, Phys. Rev. Applied **20**, 014058 (2023); DOI: 10.1103/PhysRevApplied.20.014058

https://quantnet.lbl.gov

A simpler way to connect quantum computers

A new atomic device sends high-fidelity quantum information over fiber optic networks

Princeton researchers (l–r) Sebastian Horvath, Jeff Thompson, Mehmet Tuna Uysal, Lukasz Dusanowski, and Salim Ourari (Source: S. A. Khan / Fotobuddy)

Researchers have a new way to connect quantum devices over long distances, a necessary step toward allowing the technology to play a role in future communications systems. A new study details the basis for a new approach to building quantum repeaters. It sends telecom-ready light emitted from a single ion implanted in a crystal. The effort was many years in the making, according to lab leader Jeff Thompson. The work combined advances in photonic design and materials science. The new device is based on a single rare earth ion implanted in a host crystal. Because it emits light at an ideal wavelength, it requires no signal conversion.

The device has two parts: a calcium tungstate crystal doped with just a handful of erbium ions, and a nanoscopic piece of silicon etched into a J-shaped channel. Pulsed with a special laser, the ion emits light up through the crystal. But the silicon piece, a whisp of a semiconductor stuck onto the top of the crystal, catches and guides individual photons out into the fiber optic cable. Ideally, this photon would be encoded with information from the spin of an ion, Thompson said. In a quantum repeater, collecting and interfering the signals from distant nodes would create entanglement between their spins, allowing end-to-end transmission of quantum states despite losses along the way.

To demonstrate that the new material is suitable for quantum networks, the researchers built an interferometer where photons randomly pass through one of two paths: a short path that is several feet long, or a long path that is 22 miles long made of spooled optical fiber. Photons emitted from the ion can go on the long path or the short path, and about half the time, consecutive photons take opposite paths, and arrive at the output at the same time.

When such a collision occurs, quantum interference causes the photons to leave the output in pairs if and only if they are fundamentally indistinguishable – having the same shape and frequency. Otherwise, they leave the interferometer individually. By observing a strong suppression up to 80 % of individual photons at the interferometer output, the team proved conclusively that the erbium ions in the new material emit indistinguishable photons. (Source: Princeton U)

Reference: *S. Ourari* et al.: Indistinguishable telecom band photons from a single Er ion in the solid state, Nature **620**, 977 (2023); DOI: 10.1038/s41586-023-06281-4

Quantum storage of entangled photons

Long-lived quantum entanglement goes the distance

The group of Xiao-Song Ma at Nanjing University reports record-long quantum storage at telecom wavelengths on a platform that can be deployed in extended networks, paving the way for practical large-scale quantum networks.

Quantum repeaters store the fragile entangled state and transform it into another quantum state that shares entanglement with the next node down the line. In other words, instead of amplifying the signal, the nodes are stitched together, exploiting their unique quantum properties. At the heart of such quantum-repeater networks are quantum memories in which quantum states of light can be stored. Realizing these memories with a sufficiently long storage time is an outstanding challenge, especially for photons at telecom wavelengths. Hence the excitement as Ming-Hao Jiang, Wenyi Xue and colleagues in the group of Xiao-Song Ma now report storage and retrieval of the entangled state of two telecom photons with a storage time of close to two microseconds. This is almost 400 times longer than what had been demonstrated before in this field and therefore is a decisive step towards practical devices.

The memories are based on an yttrium orthosilicate (Y_2SiO_5) crystals doped with erbium ions. These ions have optical properties that are almost perfect for use in existing fiber networks, matching the wavelength of around 1.5 µm.

In addition, the researchers combined their quantum memory with a novel source of entangled photons on an integrated chip. This demonstrated ability to both generate high-quality entangled photons at telecom frequencies and store the entangled state, all on a solid-state platform suitable for low-cost mass production, is exciting as it establishes a promising building block that might be combined with existing large-scale fiber networks – thereby enabling a future quantum internet. (Source: Nanjing U)

Reference: *M.-H. Jiang* et al.: Quantum storage of entangled photons at telecom wavelengths in a crystal, Nat. Commun. **14**, 6995 (2023); DOI: 10.1038/s41467-023-42741-1

Robust, compact quantum sensors to deliver unprecedented precision

Accuracy and sensitivity for applications including medical, navigation, brain computer interfaces (BCI), and many more

Katrin Kobe

Source all images: Bosch

Quantum sensing may be less well known than quantum computing but its impact on our world may be just as significant. Quantum sensors promise accuracy 1,000 times greater than that provided by today's conventional sensors, opening up new applications in medicine, navigation and more. Quantum sensing is also closer to market readiness than quantum computing.

Unlike classical physics, which describes the macroscopic world, quantum mechanics introduces some counter-intuitive concepts. Quantum sensors take advantage of some of these quantum properties to become ultrasensitive to even the smallest changes in their environment.

This new generation of sensors can achieve incredible precision because of the way they are initialized and their ability to detect individual quantum states after measurement. For example, by using green laser light to excite electrons in a synthetic diamond target and looking at the number of emitted photons, we can use a photonics-based systems to measure magnetic field strengths.

Today's widely available sensors are already exceptionally accurate – but quantum sensing will deliver measurements that are a thousand times more precise. In fact, prototype sensors are already achieving this unfathomable level of accuracy. Sensors based on quantum technology will also be compact, robust, and have a wide measurement range.

▲ Quantum sensors allow extremely precise measurements.

A new generation on the horizon

Quantum technology has been around for many years. It is used every day in computers, data networks, medical imaging and lasers. These are all what we define as 'GenO' (old) systems and are based on properties that arise from an interacting ensemble of atoms in a macroscopic state.

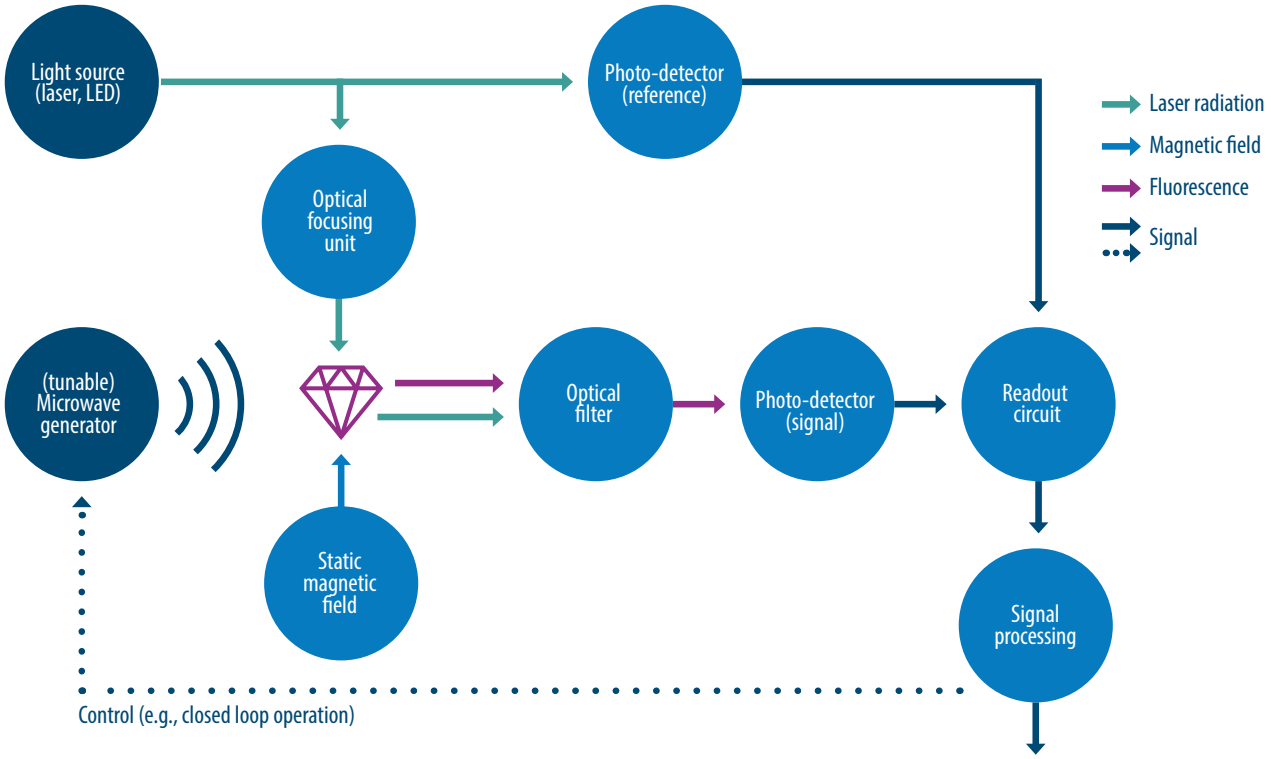


Fig. 1 Main components and sensing principle

Old generations of quantum devices exploited quantum effects in material systems, such as band gaps in semiconductors, which subsequently led to the revolutionary development of transistors and semiconductor lasers during the last century. In contrast, new developments in quantum sensing are based on 'GenN' (new) principles, focusing on individual, specially prepared quantum states to achieve breakthrough precision.

Application-specific quantum systems are being developed using state-of-the-art knowledge of quantum physics. Individual quantum entities (including individual atoms, ions or defects in solids) can be specifically addressed and utilized to act as extremely sensitive quantum measurement units.

GenN enables extremely sensitive, compact, and robust sensors with higher spatial resolution, higher sensitivity and an extremely wide measurement range.

Today's superconducting quantum interference devices (squids) and optical traps are bulky systems, requiring cryogenic cooling or a vacuum for their operation. Instead, new approaches using alkali gas cells and in particular diamonds with nitrogen vacancy (NV) centers can be made much smaller, while taking advantage of economies of scale. As a result, they hold great promise for use in cost-sensitive, high-volume applications.

Quantum sensing in practice

Let's take a closer look at a real-world example of quantum sensing and how it works in practice. Developed by Bosch Quantum Sensing, an internal start-up established at the beginning of 2022 following many years of research activity, it is a quantum magnetometer to measure tiny magnetic fields. Anything with electrical activity generates a magnetic field, but these fields can be very small. Bosch Quantum Sensing's prototype magnetometer uses a diamond as its target, with nitrogen atoms added in small numbers as a defect, known as NV centers. This is an excellent material to use because the extra nitrogen atoms provide extra electrons that act as tiny magnetic field-sensing elements.

In addition, these NV centers give the diamond specific optical and electronic properties: when it is illuminated with green laser light, the electrons jump to a higher energy level, only to subsequently return, emitting photons that are visible as red light in the process, and which are detected using a photodiode.

The key phenomenon is that the energy levels of the NV center are sensitive and respond to changes in the external magnetic field, and enable it to function as a magnetometer due to the Zeeman effect. In the long term, this could be used to observe the electrical activity in your brain, for example. Importantly, these states have a lower photoluminescence intensity – meaning that when electrons occupy these states, we will notice a drop in the intensity of the emitted red photons.

To experimentally determine the external magnetic field, we vary the microwave frequency while monitoring the intensity of the red light emitted by the diamond.

Applications for quantum sensing

The precision of quantum sensing opens up entirely new applications, from analysis of the ground beneath our feet and exploration for mineral resources, to

Company

Bosch Quantum Sensing

After years of successful research, Bosch founded the internal start-up Bosch Quantum Sensing at the beginning of 2022. Bosch is now developing business models for the commercialization of quantum sensors.
The goal is to establish Bosch as a global leader of quantum sensing products and solutions that improve the quality of life for all people around the world.

www.bosch-quantumsensing.com

medical applications or the development of very robust navigation.

In medical applications, for example by measuring the heart's natural magnetic field and enabling straightforward, contactless long-term measurements, magnetic field quantum sensors can provide far more data than today's electrocardiography (ECG).

Consumer health applications are another potential opportunity, extending the scope of monitoring that is already provided by devices such as smartphones and watches. For example, quantum sensors could be used for mobile cardiograms to continuously monitor heart activity, an interesting application for drivers in motor vehicles.

In navigation systems such as those installed in cars and aircraft, a quantum magnetometer could detect the unique magnetic signal originating from the earth's crust. It would provide positional information independently of signals from satellites. This paves the way for more robust navigation in the air, on the road, on water, and even underwater.

Precise measurement of magnetic field changes also has potentially lucrative applications in exploration and the detection of mineral resources. The measurements from the sensors in combination with AI will enable more accurate terrain analysis and help us take the guess work out of determining the right place to drill for underground resources.

Quantum sensors will lead to a wide range of improvements in industry, including the battery management systems of vehicles. Quantum sensors can be used to precisely measure the magnetic field induced by the electric current and thereby determine the exact charge level of the battery. The result would be a more reliable and precise determination of the remaining range, allowing trips to be planned better.

With regard to process improvements, quantum sensors have applications in non-destructive materials testing where their precision allows them to detect tiny imperfections such as cracks that are often missed by conventional testing methods.

Example application: Navigation

Bosch Quantum Sensing is working with Airbus to assess the possibility of enhancing the current aircraft navigation systems that enable safe flight operations today. The objective is to add dissimilar navigation information in civil aviation by utilizing quantum sensor technology for the acquisition of precise positioning data.

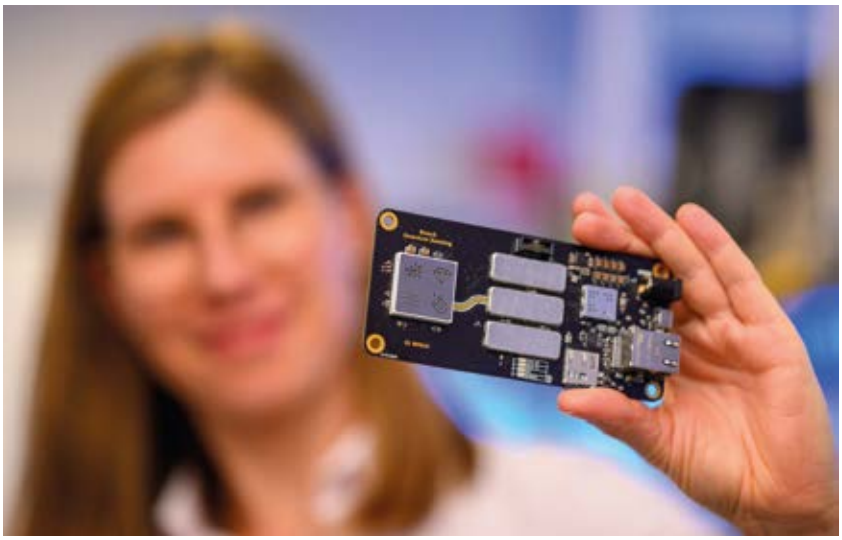


Fig. 2 The long-term goal is to achieve further miniaturization and integrate the technology on a chip.

As already mentioned, quantum sensors can measure the earth's magnetic field and provide a unique signal to enable aircraft to operate independently of global positioning signals from satellites.

Airbus and Bosch consider the use of quantum sensor technology to be a highly innovative solution for the support of all other onboard aircraft navigation systems. This has the potential to further increase flight safety by providing dissimilar data. This partnership combines Airbus' expertise in aircraft development and airborne navigation systems with Bosch's in-depth knowledge of quantum sensor technology.

Conclusions

The technology is still in development, but it is already clear that quantum sensing promises to deliver robust, compact sensors with unrivalled accuracy. Bosch's quantum sensor prototype is currently about the size of a cell phone and is the smallest currently available with this level of measurement accuracy right now, but of course, much more advanced sensors will come in the not too distant future.

Over the next two years, Bosch Quantum Sensing plans to work on specific applications with pilot customers in the medical and mobility sectors. Brain computer interfaces (BCIs) remains the long-term strategic target market for quantum sensors – but the number of other possible applications is huge. It is going to be an exciting journey to see where and how this technology improves and transforms our world.

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The quantum revolution in vehicle sensor technology

How quantum dots are empowering vehicle safety and automation features

Hao Pang

Source all images: Quantum Science

With technology like lidar heralding a revolution in vehicle automation, SWIR (short-wave infrared) imaging and sensing will become increasingly vital to the automotive sector. Quantum dots, nanoscale semiconductors tunable to SWIR wavelengths, could provide the answer to empowering SWIR and bringing enhanced capability to the mass market.

Vehicle safety technology has come a long way. In the 19th century, drivers in England were required by law to be led by someone waving a red flag or lantern to warn pedestrians and horse-drawn carriages that an automobile was approaching. Today, things are a little more advanced.

From time-of-flight (ToF) sensors to in-cab driver monitoring, breakthroughs in photonics have helped to revolutionize technology that improves road safety – and as the materials that power this technology advance, it will only become more effective.

In fact, photonics systems have reached the point where something that once seemed the stuff of science fiction – self-driving cars – may not be too far out of reach. But for this technology to reach consumer markets, car manufacturers will need to incorporate the latest in sensing and imaging technology.

Quantum dots (QDs) – nanoscale semiconductor materials responsive to short-wave infrared light – are the answer. Already facilitating breakthroughs in sensing systems, these tiny technological marvels could be key to enhancing existing vehicle safety features and to making truly autonomous roadways a reality.

▲ A sample of quantum dot ink in a small vial, held by a Quantum Science employee

SWIR for vehicle safety

Many vehicle safety systems on the market today rely on near-infrared (NIR) sensors. For example, ToF technology, which is used to help cars detect their surroundings, involves shining an infrared light on surfaces outside the vehi-

A spectrophotometer used to measure the absorption spectrum of quantum dots

cle and comparing the light's reflection with the emitted signal. This reflection is used to create a point cloud, and the travelling time of light between the emitter and object are measured to create a 3D picture of the scene.

However, this reliance on NIR sensors can affect ToF technology's performance. Many common conditions, such as bright ambient sunlight, precipitation, or external shadows, can confuse NIR cameras and limit the quality of the data they can deliver.

Other driver safety technologies face similar challenges. Some markets are beginning to mandate driver monitoring systems such as in-cabin cameras to track driver behavior. These systems typically use NIR cameras inside a cabin to record the driver, monitoring things like hand position and eye movements to gauge distraction levels and create a safer driving environment. However, here the NIR light can also be disrupted by environmental conditions.

Switching to SWIR can significantly improve the functionality of driver monitoring systems. SWIR sensors operate effectively even at night and are not affected by ambient glare. SWIR light can also be used with much more power while remaining eye-safe, further increasing precision without compromising driver safety.

Quantum dots present the best option for introducing SWIR capability to markets, including the automotive sector. Equipped with QD-powered SWIR sensors, these cameras will be better able to function in strong light conditions and at night, capturing information much more effectively than current solutions.

Unlocking vehicle automation

Self-driving cars are a long-standing goal for the automotive industry. For decades, the potential has been recognized for this technology to transform transport, making journeys more convenient, enjoyable, and safer for everyone.

Most experiments with vehicle automation are focused on light detection and ranging (lidar) technology. Lidar systems use narrow lasers and photoreceptors to generate high-resolution terrain maps. Using this approach means lidar-equipped vehicles can in theory automatically detect obstacles and navigate around them. Lidar excels in terms of versatility and accuracy, generating more precise images than alternative technologies and operating with greater flexibility.

However, this technology suffers from drawbacks, including a high cost and limited performance in poor environmental conditions such as dust and smoke. Relying on visible light alone means that it may also miss many essential data points. Truly autonomous vehicles must be able to 'see' in all weather conditions, detect dangerous black ice patches even at night, and operate efficiently in bright sunlight.

Incorporating SWIR sensors into lidar technology will better equip autonomous vehicles to identify hazards, even in low light or obscured conditions. What is more, SWIR sensors can also be used to detect and differentiate between dry, wet, and icy road conditions because ice and water have different SWIR absorption coefficients – enabling SWIR-equipped vehicles to automatically adjust their steering depending on the road conditions.

SWIR capability could even be used to boost the effective range of lidar from 200 to 500 meters, without risking potential eye damage to bystanders or other drivers. Although this functionality is still a few years away in terms of development, the automotive industry can begin planning for its integration now based on breakthroughs in SWIR-capable QD technology.

The quantum solution

Most SWIR sensors in use today are made from compounds such as indium-gallium-arsenide (InGaAs). Although InGaAs sensors offer high performance and are capable of absorbing SWIR light at wavelengths of up to 1.7 µm, they are also prohibitively expensive at a cost

Company

Quantum Science

QS is a leading British materials innovation company that focuses on developing and commercializing QDs, nanomaterials, and technologies for imaging and sensing markets. QS has a team of experts in QD synthesis and scaleup, nanocrystal and nanoparticle surface engineering, ink formulation, thin-film processing and QD semiconductor device engineering.

www.quantumscis.com

A scientist operating an atomic force microscope (AFM) used to measure the properties of quantum dot films

of around 10,000 US dollars per unit. The requirement for cooling systems on InGaAs sensors can also render them unwieldy and make them unsuitable for commercial or automotive applications.

Silicon-germanium sensors offer a more affordable alternative but are held back by the inherent performance limitations of silicon, which is transparent under most SWIR light.

QDs offer a solution to both problems. Tunable to almost any wavelength across the visible, NIR, and SWIR spectra, today's QDs offer high performance, outstanding pixel pitch and spectral range, and cost just a fraction of InGaAs solutions. As a result, they represent the most effective solution to integrate SWIR capability into automotive applications.

However, restrictions on lead have so far limited the commercialization of QDs. The best performing QDs have traditionally been based on heavy metals, the inherent toxicity of which renders them unsuitable for many applications and markets. Although lead-free alternatives existed, most were unable to offer the performance required for most imaging and sensing applications and were limited to wavelengths of 1,100 µm at most.

Recent breakthroughs in QD formulation have changed the game. Quantum Science, the infrared technology expert company, has successfully created lead-free INFIQ quantum dots sensitive to wavelengths of up to 1,550 nm, a level of performance unmatched elsewhere in the industry. Thanks to a unique production process, this technology offers enhanced material uniformity and stability and can be produced at a sufficient scale to supply the vast emerging demand in consumer and automotive applications.

Photonics is changing how we interact with the world around us. The latest camera and sensor technology can capture vast quantities of invisible data, unlocking leaps and bounds in everything from medical imaging to vehicle safety and automation. As the automotive industry seeks to enhance safety systems and overcome the hurdles that are keeping self-driving vehicles out of the market, this technology will give manufacturers the acceleration they need.

DOI: 10.1002/phvs.202300038

Further reading: *Stuart Stubbs (Quantum Science):* How the hidden quantum realm reveals the invisible – tunable quantum dots offer a sought-after breakthrough in SWIR sensing and imaging, PhotonicsViews **20**(6), December 2022, p. 38; DOI: 10.1002/phvs.202200046

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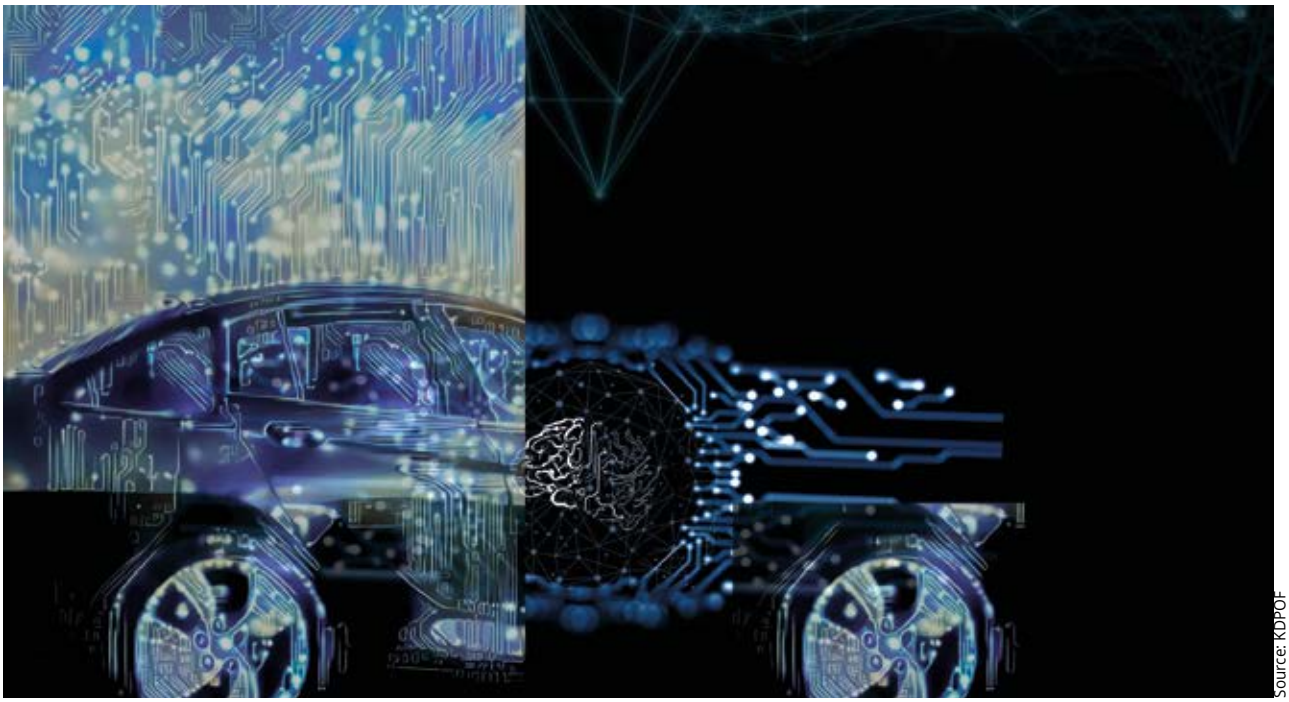
Optical neurons to interconnect sensors and artificial brains in autonomous vehicles

Fiber optics connectivity based on long-wavelength VCSELs and fully-integrated and adaptive electronics

Rubén Pérez-Aranda & Joseph Pankert



Source: KDPOF

With the ever-increasing need for faster data communication in cars, electrical interconnects are beginning to show bandwidth and electromagnetic compatibility limitations. The new IEEE 802.3cz ethernet physical layer has been developed specifically to meet these needs, based on a long-wavelength multimode VCSEL (vertical cavity surface-emitting laser) and mature bend-insensitive multimode fibers. A major innovation is taking place that will make automotive-grade, multigigabit optical transceivers possible.

In recent years, the automotive industry has witnessed a remarkable transformation with the advent of advanced technology. One crucial aspect that has gained significant attention in this paradigm shift is the communications infrastructure within cars. Connectivity of sensors (e.g. camera, radar, and lidar) with artificial intelligence (AI) central units is essential for sensor fusion used in advanced driver assistance systems (ADAS) and autonomous vehicles (AV).

This connectivity needs to be reliable, low latency, and at a high data rate. With the ever-increasing need for faster and more reliable data transfer, traditional electrical interconnects are beginning to show their limitations, urging the industry to explore alternative solutions. Optical interconnections are very well positioned for several reasons: much-needed data rates, superior electromagnetic compatibility (EMC) performance, and future-proven data rate density scalability.

Automotive applications, however, require the ability to operate under more stringent environmental conditions, with higher reliability requirements, cost constraints, and a high production volume compared to data center optical links. This has led to a new set of specifications for the optical links, which are covered in this article.

Standardized optical links in automotive applications

Compared to telecom and data centers, where optical fiber interconnect deployments are very common, automotive applications require a much wider range of operating temperatures, superior reli-

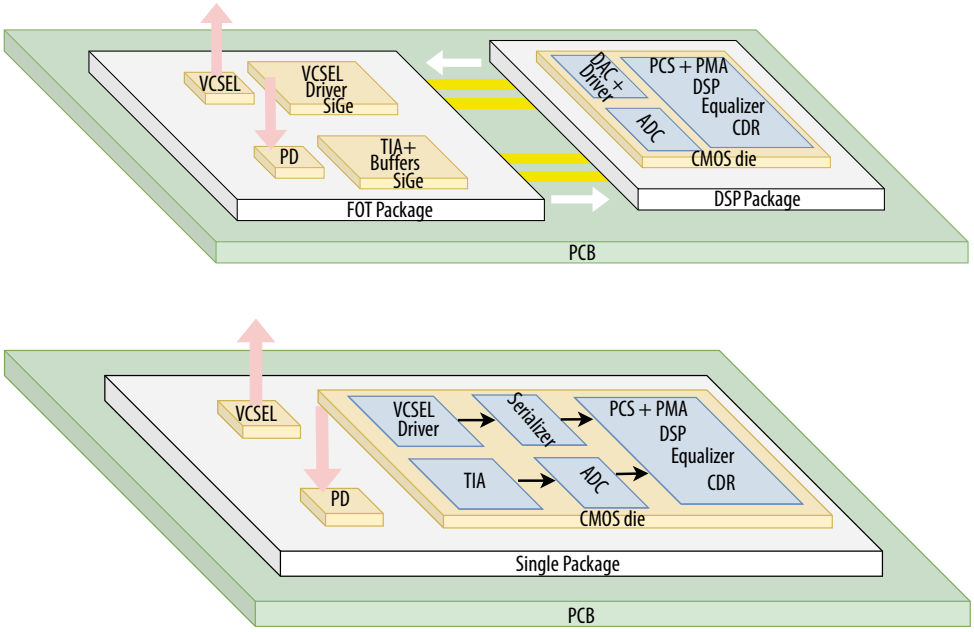


Fig. 2 Comparison between implementations of an optical transceiver for data center application (top) and an optical transceiver for automotive application (bottom; source: KDPOF)

ability, and the implementation of specific dependability and safety functions. A new optical physical layer standard was issued in March 2023 – IEEE Std 802.3cz – supporting data rates of 2.5, 5, 10, 25, and 50 Gb/s (single lane). It supports implementations qualified according to AEC-Q100 grade 2 (ambient temperature from -40 to 105 °C within the electronics control unit, ECU). This is equivalent to a backside temperature of up to 125 °C due to the heat dissipation of the many devices fitted on the same printed circuit board (PCB).

This standard was designed to maximize the link budget of a maximum forty meter link (for connectivity in cars, buses, and trucks). It supports optical connections with a high insertion loss (up to four inline connections) where the main noise source is the receiver circuit. This approach is different from the data center physical layer specifications where sensitivity is fundamentally limited by the optical fiber effective modal bandwidth (EMB) and the noise sources defined in the transmitter, i.e., the relative intensity noise (RIN) and modal partition noise (MPN).

IEEE Std 802.3cz was designed to allow implementations with data-aided adaptation of the receiver circuits using minimum mean square error (MMSE) optimal techniques for timing recovery and channel equalization. These techniques together support, on the one hand, non-linear distortion equalization of the optical signal produced by the VCSEL when it is operating at extreme temperatures and, on the other hand, operation of the system under null-eye conditions in the receiver. These algorithms are fundamental for high yield and low power transceiver production because they allow variations caused by temperature, intra-die / inter-die mismatches and fabrication process to be efficiently handled.

This standard specifies a new test method called transmitter distortion figure of merit (TDFOM), which includes a reference receiver with signal filtering, timing recovery, and MMSE feed-forward and decision feedback equalizer. This method is used to validate interoperable transmitters and to calibrate reference transmitters that are employed for receiver sensitivity testing.

IEEE Std 802.3cz includes support for the implementation of advanced diagnosis of the link, wake-up / sleep functions and dependability functions by means of an operations administration and maintenance (OAM) channel. It also includes the specification of energy-efficient Ethernet (EEE) operation for power saving in low traffic conditions and asymmetric rate use cases.

Optical devices for automotive applications

The basic optical building blocks of future optical interconnects in cars are not different from the short-reach interconnects in data centers that support Ethernet: electrical data are transformed into an optical signal by means of a laser; the laser-modulated intensity is fed into an optical fiber and re-transformed into an electrical signal by means of a photodetector at the other end of the fiber.

The main benefits of choosing VCSELs as the preferred laser source are the easy optical fiber coupling through a circular beam profile, a high-volume manufacturing capability, a high-speed modulation capability, and the lowest power consumption.

Many of the VCSELs used in today's data interconnects operate at a wavelength of 850 nm. This preference traces back to the original 10G Ethernet stan-

Company

KDPOF

KDPOF is a fabless semiconductor supplier that provides high-speed optical networking solutions for the automotive industry. Founded in 2010 in Madrid, Spain, KDPOF innovates in information theory, DSP, analog mixed-signal, optical coupling, and packaging designs. It markets cost-effective technology such as fully qualified automotive-grade ASSPs, integrating electronics, photonics, and optics in a single package. KDPOF currently has partners and coworkers in France, Germany, Korea, Japan, USA, China, and Sweden.

www.kdpof.com

Company

TRUMPF Photonic Components

TRUMPF Photonic Components is a global technology leader, supplying VCSEL and photodiode solutions for the consumer electronics, datacom, automotive, industrial sensing and heating markets. So far, more than two billion VCSEL chips and photodiodes have been shipped worldwide. The company has its headquarters in Ulm, Germany, with further sales locations in the Netherlands, China, Korea, and the USA.

www.trumpf.com

dard (IEEE Std 802.3ae) where 850 nm was selected primarily due to the availability of GaAs photodetectors capable of matching this wavelength. The industry has since been constrained by the need for interoperability between new transceivers and older generations, thus perpetuating this historical choice, even though the majority of VCSELs currently operate at 940 nm, primarily for non-datacom applications. The wide availability of InGaAs photodetectors with a broad photosensitivity range spanning from 800 nm to 1,100 nm also removes any limitations on wavelength selection in cases where backward compatibility is not required.

Optical interconnects in automotive applications are not subject to backward compatibility requirements. The industry can therefore make the best wavelength choice based on technical and commercial performance. This choice was recently made through the release of the IEEE Std 802.3cz standard where the wavelength center range was specified as 970 – 990 nm (clause 166.6.3.2). The wavelength choice was driven by the high operating environmental temperature (up to 125 °C) and the associated challenges of having a long operating life.

Automotive optical transceivers

The optical transceiver is at the core for the implementation of the whole solution. Traditional approaches of data center optical transceivers based on pluggable modules (such as SFP, QSFP) are not suitable for automotive applications. New implementation approaches need to be developed, paying special attention to microelectronics circuit design, integrated circuit (IC) hybrid packaging, and optical connectivity aspects.

Optical transceivers have to be designed in a small package with full integration of electronics, photonics and optics into a single component that must support standard assembly on a PCB as with any other standard surface-mounted component. The optical transceiver therefore needs to be compatible with standard pick-and-place and reflow processes.

New implementation approaches considering the technology node selection constraints, the analog-digital design partitioning, the photonics, and the optics integration need to be developed that take into account the reliability and quality requirements of the intended application from the earliest design stage.

Fig. 2 illustrates a typical transceiver design and, below, the automotive version. Traditional data center optical communications solutions are based on dedicated transceivers, which only embed optical-electrical conversion, the fiber optics transceivers, FOTs. The FOT communicates by means of digital electrical signals with a separate component that implements the digital signal and protocol processing tasks (i.e. a DSP). The FOT component is assembled with optics and optical connector in a specific separately pluggable module (such as the SFP module), together with a VCSEL and photodetector (PD) and optoelectronics dies (VCSEL driver and trans-impedance amplifier, TIA). The VCSEL driver and TIA are fabricated using specific SiGe BiCMOS nodes. The DSP component is fabricated in a deep, sub-micron bulk CMOS node and assembled in a standard IC package.

Source: Trumpf

Fig. 3 SEM picture of 1 × 6 bottom-emitting VCSEL arrays with integrated collimating lenses. The VCSELs are mounted on a carrier for characterization.

Automotive applications require a single component solution for several reasons. The cost is reduced from that of two packages with five or more dies down to one single package composed of three dies. High speed signals connecting both the FOT and DSP components are removed, reducing EM emissions and improving EM immunity. Linear signaling can be efficiently used between the DSP and optoelectronics, allowing much more sensitive receiver implementations. Integration in one single die brings lower power consumption, and bulk CMOS enables low cost, high volume, and automotive quality production.

VCSELs for automotive applications

The underlying failure mechanisms of VCSELs and related test methods have been extensively studied in the literature [3, 4, 5]. These failure mechanisms are categorized into wear-out failures, where material degradation occurs over time as a function of temperature and current density, and random failures that are linked to material defects and

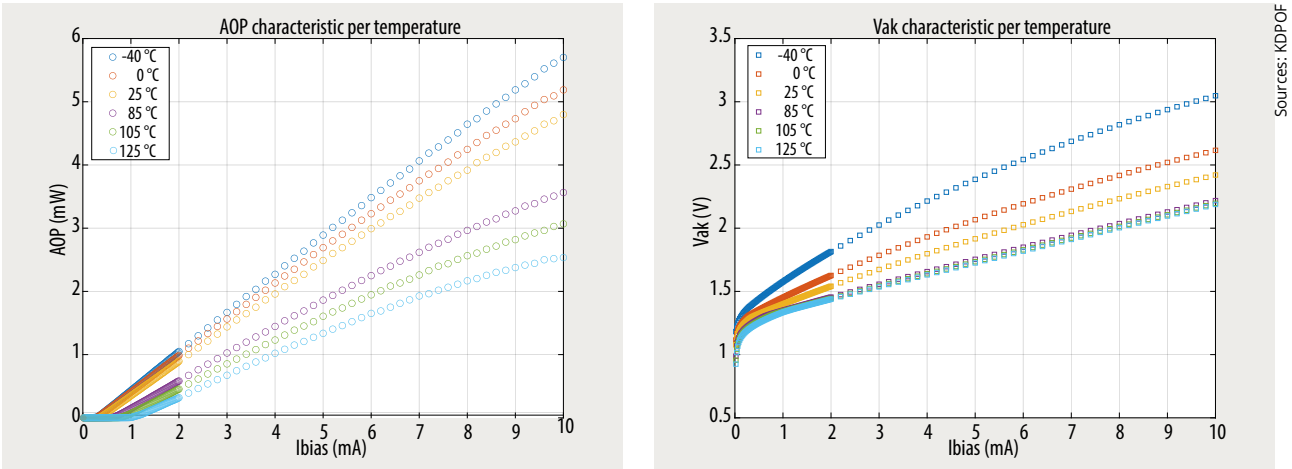


Fig. 4 Power output (left) and voltage drop (right) characteristics of 980 nm VCSELs for different temperatures. The VCSELs had an aperture of 7 µm in diameter.

the propagation of these defects during operation.

Extensive research has been conducted on 980 nm VCSELs, primarily for high-power applications. These applications often involve the use of large arrays of VCSELs for tasks such as material processing, including drying and annealing, operating with high current densities close to roll-over and a high junction temperature. 980 nm and longer wavelength VCSELs have demonstrated remarkable resistance under extreme conditions, showing no signs of degradation after many thousand hours of operation [2].

Long wavelength VCSELs of 940 nm and above are constructed using InGaAs quantum wells, which exhibit superior reliability compared to traditional short wavelength VCSELs based on GaAs quantum wells. They are superior in both wear-out and random failure characteristics. Regarding wear-out: typical activation energies for InGaAs are 1.3 eV, versus 0.7 eV for GaAs, which leads to a significantly longer lifetime [5]. With regard to random failures: GaAs is susceptible to dislocation propagation (referred to as dark line defects), whereas In-containing quantum wells introduce compressive strain into the material, preventing defect propagation.

In-containing quantum wells have also become the state-of-the-art in 850 nm VCSELs in recent years, resulting in an important improvement of VCSEL reliability in data centers. Nevertheless, 980 nm VCSELs offer unique advantages, allowing for the incorporation of high levels of In (>20 %) and delivering lifetime properties unmatched by any 850 nm devices so far (see Fig. 6).

Many groups have explored wavelengths of 980 nm and longer in the context of data transmission [1, 6]. Beyond their resistance to high-stress conditions, the motivation for using 980 nm, particularly in comparison with 940 nm, is the potential for employing VCSELs in bottom emitter configuration where the light exits from the from the backside of the GaAs substrate. This configuration is unfeasible for short wavelengths (like 850 nm) due to light absorption in the substrate. This feature enables flip-chip implementations, which are attractive for improving signal integrity and enabling self-alignment in the assembly of transceiver components. The same consideration applies to InGaAs/InP 980 nm bottom illuminated photodetectors.

Trumpf has generated an extensive data set on long-wavelength, bottom-emitting VCSELs ranging from 980 to 1,090 nm, all of which demonstrated exceptional suitability for automotive interconnects. These VCSELs were grown epitaxially on semi-insulating GaAs substrates and featured multiple oxidation layers. Doping and band-gap grading techniques were employed to reduce mirror resistance. As an additional feature, collimating lenses were etched into the back of the chip, eliminating the need for external collimating lenses. An SEM photo can be seen in Fig. 3. These lenses are passive elements and did not impact the electrical and lifetime properties of the device. The devices were measured to assess their electro-optical and high-frequency properties.

Fig. 4 shows the temperature dependencies (measured in the backside) for optical power and voltage drop in the

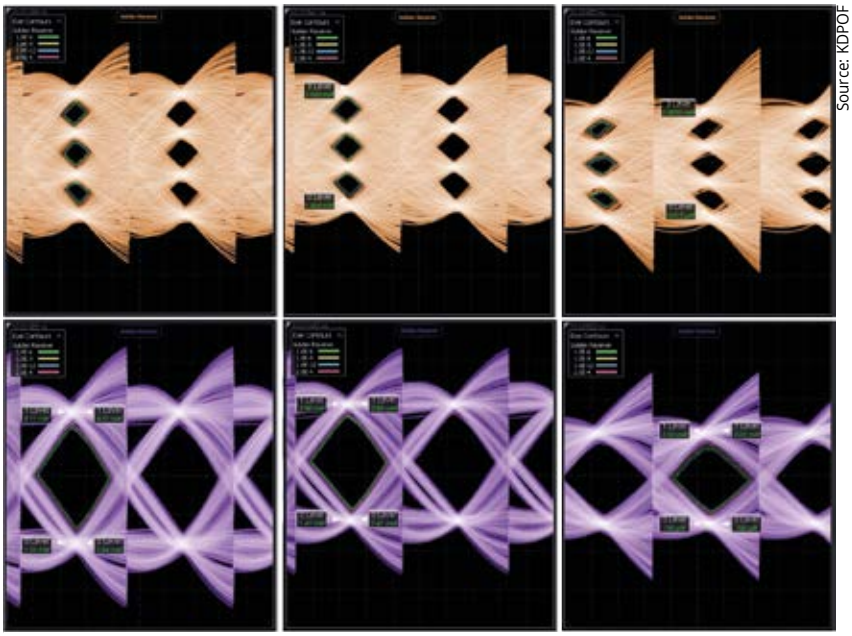


Fig. 5 Eye diagram of a TDFOM reference receiver. Top: 50 Gb/s PAM4. Bottom: 25 Gb/s NRZ. Transmission was through 40 m OM3 fiber. The drive current is 7 mA and the extinction ratio (ER) 4 dB in all cases.

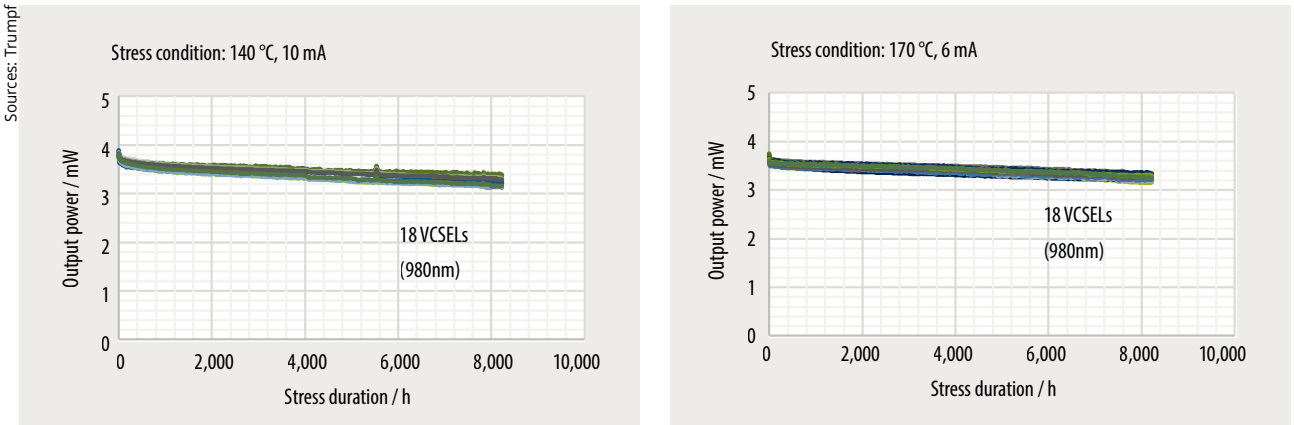


Fig. 6 Wear-out behavior of two sets of 18 VCSELs each, stressed under 140 °C / 10 mA and 170 °C / 6 mA for 8,000 hrs. The aperture size was 7 µm in all experiments.

full range from -40 to 125 °C. Electrical-to-optical bandwidth exceeded 18 GHz at -3 dB. The final validation of compatibility with IEEE Std 802.3cz specifications was accomplished through large signal characterization. Fig. 5 shows oscilloscope screenshots that demonstrate the operation of 25 and 50 Gb/s performance, once again across the full temperature range. Non-return to zero (NRZ) modulation is used for 25 Gb/s operation, whereas pulse amplitude modulation of four levels (PAM4) is employed for 50 Gb/s. The screenshots show the eye diagram of the signal generated by 980 nm VCSELs, operating at different backside temperatures and after being transmitted over forty meters of OM3 fiber. Eye diagrams are measured at the output of the TDFOM reference receiver, per IEEE Std 802.3cz.

VCSEL reliability results

Numerous devices underwent extensive life testing under various demanding conditions. As depicted in Fig. 6, we present two examples from a set of eighteen VCSELs subjected to stress conditions of 140 °C / 10 mA and 170 °C / 6 mA, respectively. None of these VCSELs failed after continuous operation of 8,000 hours, and there was no noticeable degradation in power output. The testing, which included additional measurements for different wavelengths, was then discontinued as it did not yield any activation energy values that would enable the development of a wear-out reliability model. In essence, the samples exhibited exceptional reliability by not experiencing any failures. Other tests according to Telcordia Standard GR-468 were successfully passed, with no observed deterioration in performance.

Conclusions

As vehicles continue to evolve into smart, connected entities, the need for advanced communication technology becomes increasingly important. Optical interconnects with their superior EMC performance and future-proven data rate density scalability offer a solution to this challenge. Environmental requirements and the request for utmost reliability and lifetime (i.e., zero defects) of the automotive application were the fundaments behind the development of IEEE Std 802.3cz. It enables the implementation of fully integrated automotive-grade optical transceivers using suitable bulk CMOS technology nodes with 980 nm VCSEL technology. The use of 980 nm VCSELs overcomes the reliability limitations of traditional 850 nm devices used in data centers.

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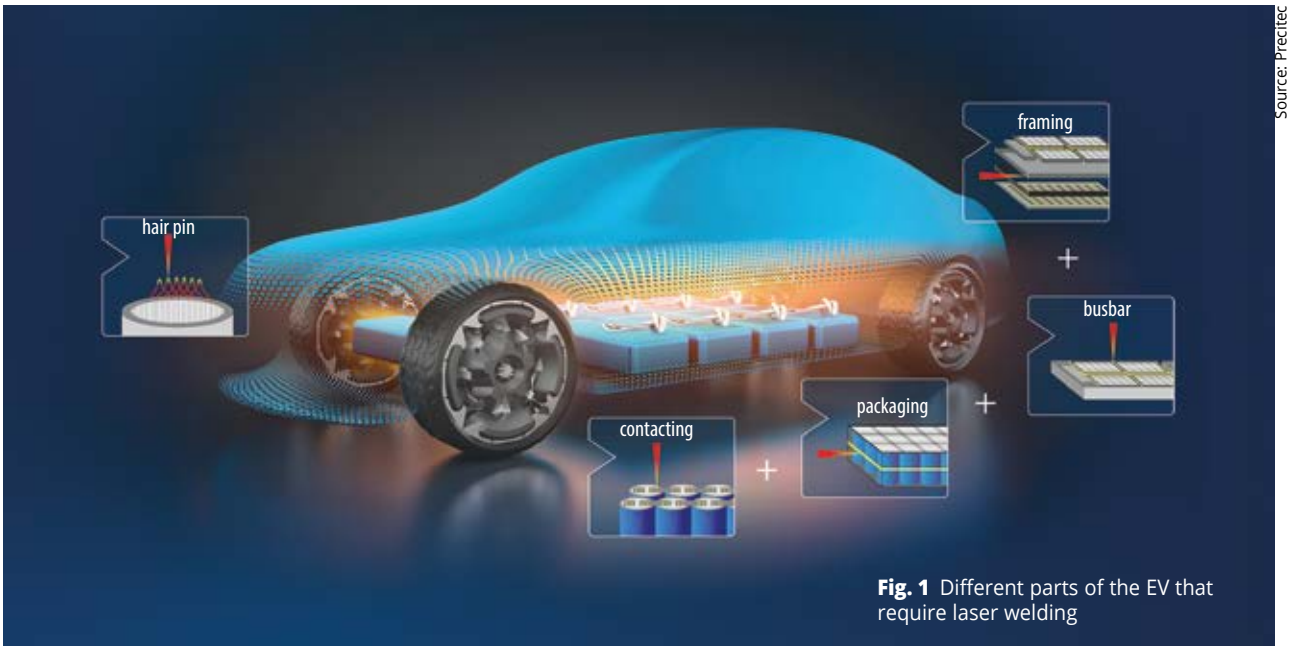
Addressing challenges in electric vehicle production

Advancements in beam shaping technology for enhanced laser welding of copper

Gwenn Pallier



Source: Precitec

Fig. 1 Different parts of the EV that require laser welding

The electric mobility (e-mobility) revolution is upon us, driven by the imperative need to reduce carbon emissions, navigate evolving political landscapes, and meet societal expectations.

Electric vehicles (EVs) represent a beacon of hope in this transformation. They promise a sustainable future, aligning with stringent emissions standards and attracting government incentives globally. However, the journey towards e-mobility is not without hurdles. To truly accelerate the adoption of EVs, we must tackle the challenges of cost reduction, increased driving range (autonomy), and enhanced safety. This article delves into a cutting-edge laser beam shaping technology that addresses these challenges, particularly within the context of copper laser welding in electric vehicle manufacturing.

The significance of electric mobility

Electric mobility has emerged as a formidable force in the automotive industry, with far-reaching environmental, political, and societal implications. Let us explore these facets in greater detail.

Environmental impact: the environmental imperative is arguably the most compelling driver of electric mobility. Traditional internal combustion engine vehicles are major contributors to greenhouse gas emissions. The urgency to combat climate change has never been more apparent, and EVs offer a potent solution.

Political and regulatory initiatives: governments worldwide have embarked on a mission to encourage electric vehicle adoption through regulatory initiatives. More and more countries, especially in Europe and in the US, are implementing policies such as tax incentives, subsidies, and emissions standards to promote the transition to EVs.

Societal expectations: beyond environmental concerns and political incentives, societal expectations are playing a pivotal role. Consumers are increasingly seeking eco-friendly transportation options. They desire vehicles that align with their values of sustainability and environmental responsibility.

Challenges in electric car adoption

While the EV market has seen remarkable growth, certain obstacles hinder the full-scale adoption of electric vehicles. The three primary challenges we aim to address are:

1. Cost reduction: electric cars are often perceived as more expensive than their gasoline counterparts. The primary driver of this cost differential is the high price of the batteries. Achieving cost reduction is crucial to making EVs accessible to a broader consumer base.

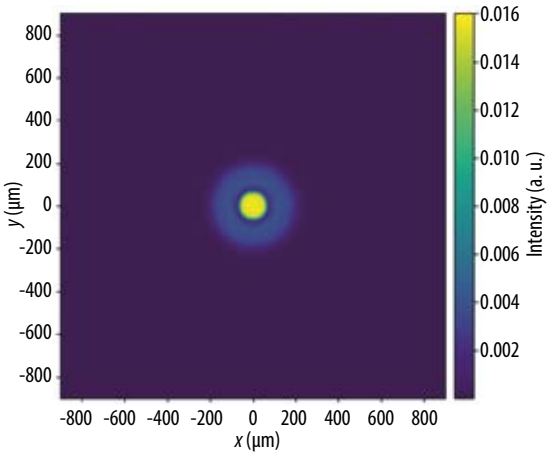


Fig. 2 Targeted (theoretical) intensity profile in the processing plane of the MPLC beam shaper

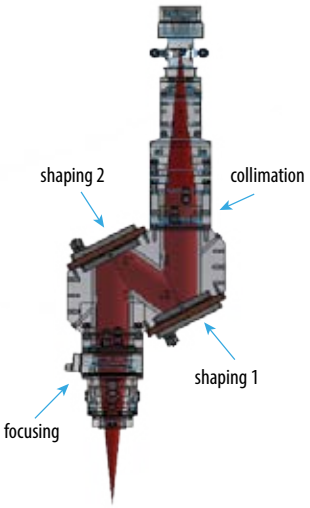


Fig. 3 Schematic of the laser head principle used to weld copper

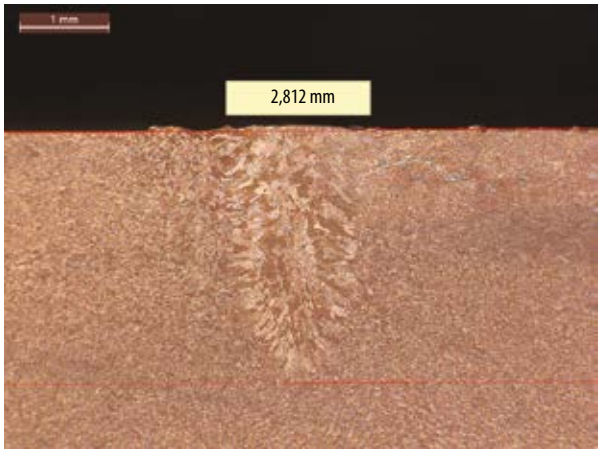


Fig. 4 Macrographic of 3 m/min 8 kW copper welding

2. Increased autonomy: to alleviate consumers' 'range anxiety', we must extend the driving range of electric cars. This means advancing battery technology and optimizing power management systems.

3. Safety concerns: safety is paramount in the automotive industry, particularly in the context of EVs. One aspect of safety revolves around minimizing spatter formation during the welding of copper components, such as busbars and hairpins, to ensure the reliability of EVs.

Addressing challenges with laser beam shaping technology

As seen in Fig. 1, the laser industry is involved in and developing solutions for multiple parts of the EV.

To confront these challenges head-on, laser beam shaping based on multiplane light conversion (MPLC) technology has been developed. This technology significantly enhances the copper laser welding process within electric vehicle manufacturing. The MPLC-based systems have been developed to provide process improvements of two parts: hairpins and busbars. These are both made of copper, which is challenging due to its high reflectivity and conductivity. Another challenge are the especially high quality welding standards for e-mobility (very few pores and spatters).

The system helps through a substantial expansion of the process window and an extension of the depth of field. Let's delve into the development process and take a deeper look into the advantages of this innovation.

Development and testing

Testing at the Maupertuis Institute: initial testing focused on copper samples, where various beam sizes and energy ratios were applied. The fundamental pattern that was used consisted of a dot and a ring, strategically designed to initiate and stabilize the welding process, as pictured in Fig. 2.

The system is made of standard collimation and focusing optics from Precitec and beam-shaping mirrors developed, manufactured, and assembled by Cailabs as detailed in Fig. 3.

This configuration was put to the test across a wide spectrum of welding speeds (ranging from 3 to 15 m/min) and laser powers (varying between 4 and 8 kW). Remarkably, the technology consistently yielded compliant welds across the entire range, except for one specific condition – 4 kW at 15 m/min. This represents a remarkable 1.5 times larger process window when compared to conventional double-core fiber lasers with which lower speed welding was not possible.

For example, a penetration depth up to 2.8 mm has been obtained for a configuration with a 125 µm dot, 500 µm ring, 50 % energy in both sub-shapes, welding at 3 m/min and power level of 8 kW as shown in Figs. 9 and 10.

Collaborative testing with the IFSW – Stuttgart University: collaborative testing with the IFSW at Stuttgart University introduced real-time monitoring of the welding process, thanks to x-ray equipment. This monitoring provided invaluable insights into pore formation, spatter dynamics, and the behavior of the keyhole. Not only did the results confirm the extended process window, but they also showcased the technology's ability to weld at speeds of up to 25 m/min with-

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 leading player 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

out visible pores. Post-processing x-ray analysis corroborated these findings, verifying the absence of pores within the copper samples as shown in Fig. 6.

The main purpose of the x-ray station is the live observation of the melt pool during the welding process. This analysis demonstrated that the welding had a stable penetration depth over long welds, as shown in Fig. 7.

Real-world applications

Welding actual busbars: transitioning from test samples to real components, busbars typical of both trucks (3 mm thick) and cars (1 mm thick) were successfully welded over a 1 mm copper plate. The welding configuration is shown in Fig. 8.

These welds adhered to ISO standard 13919-2, exhibiting no visible pores or spatter on the welded samples. The truck busbars were welded at 5 m/min, 8 kW, giving a penetration depth of 1 mm inside the lower part and a bond thickness of 0.8 mm. The car busbars were welded at 6 m/min, 5.5 kW, giving a penetration depth of 0.8 mm inside the lower part and a bond thickness of 1.2 mm.

This achievement served as a tangible demonstration of the technology's robustness during the trade-show Laser World of Photonics in collaboration with the Institut Maupertuis [1].

Hairpin welding with Precitec: Collaborating on EV motor manufacturing with Precitec in Gaggenau, Germany, copper hairpins were welded using a Raycus laser and a Precitec scanner head as shown in Figs. 9 and 10. This milestone holds immense significance as it showcases compatibility with various laser brands and fast, large-field-of-view scanners (200 mm × 104 mm). Welding with 6 kW at 10 m/min marks a significant stride forward, opening doors to substantial cost reduction and expanding the horizon of potential applications.

Fig. 5 Weld seam of 3 m/min 8 kW copper welding

Fig. 6 Longitudinal macrographic of 8 kW and 25 m/min copper welding

Advantages of MPLC laser beam shaping technology

Compatibility and flexibility: a prime feature of this technology is its compatibility with a wide range of laser brands and scanners. This offers unparalleled flexibility in the configuration of laser systems, thereby allowing for diverse applications. It also facilitates cost-effective integration with different lasers and scanning systems.

Enhanced process robustness: the technology effectively transforms a traditionally challenging process into a more forgiving one. It accomplishes this through several critical factors:

Fully reflective beam shaper: the technology employs a fully reflective beam shaper, ensuring stability by uniformly cooling mirrors from the rear. This unique approach enables the creation of high-power, stable systems, offering enhanced reliability.

Extended depth of field: the technology boasts an extended depth of field, preserving the desired beam shape over an impressive range (±4 mm). This is to be compared to the depth of field of double core fiber lasers, with which the actual shape is lost at +2 mm from the focus. This feature simplifies complex tooling development and accommodates imperfect alignments and curvatures. Even at the edge of the field of view, the technology excels.

Large process window: with a process window 1.5 times greater than that of double core fiber lasers, the technology demonstrates robustness. It consistently produces compliant welds with minimal optimization, making it suitable for a broad spectrum of welding conditions.

Customization and adaptability

Tailoring to specific applications: one of the technology's most striking features is its ability to tailor beam shapes

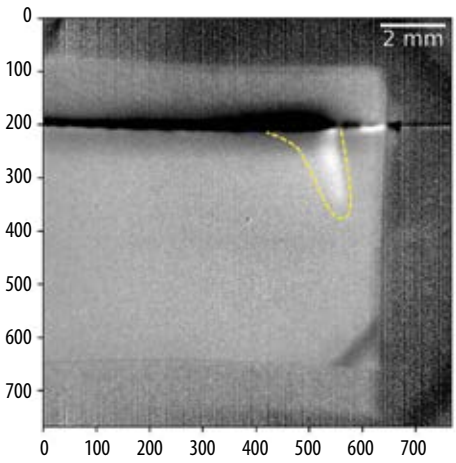


Fig. 7 Averaged image of x-ray live imaging of copper welding

Fig. 8 Welded car and truck busbars

to meet the unique requirements of each application. This level of customization surpasses conventional methods, which often have limited beam shape options. The technology offers unmatched adaptability to diverse welding scenarios.

Integrated add-ons: the technology also accommodates the integration of add-ons, empowering customers to equip their systems with additional features such as gas management, monitoring equipment (e.g., high-speed cameras), and safety enhancements (e.g., photodiodes). This integrated approach streamlines system setup, ensuring comprehensive functionality.

Compact footprint: the adaptability of this technology extends to various customer constraints, allowing for the provision of compact solutions tailored to specific spatial requirements.

Fig. 9 Hairpins welded with an MPLC-based system

Fig. 10 Macrographic of the hairpins welded with an MPLC-based system

Summary

In conclusion, the innovative MPLC laser beam shaping technology we have explored in this article holds promise for the advancement of electric vehicle manufacturing. With the intricate details provided here, we have unveiled the remarkable potential of this technology to drive electric vehicle adoption through cost reduction, extended autonomy, and enhanced safety. As the e-mobility market continues to evolve, this technology stands as a testament to the industry's commitment to achieving a sustainable and accessible electric future.

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[1] https://youtu.be/su4SDLWJYNk

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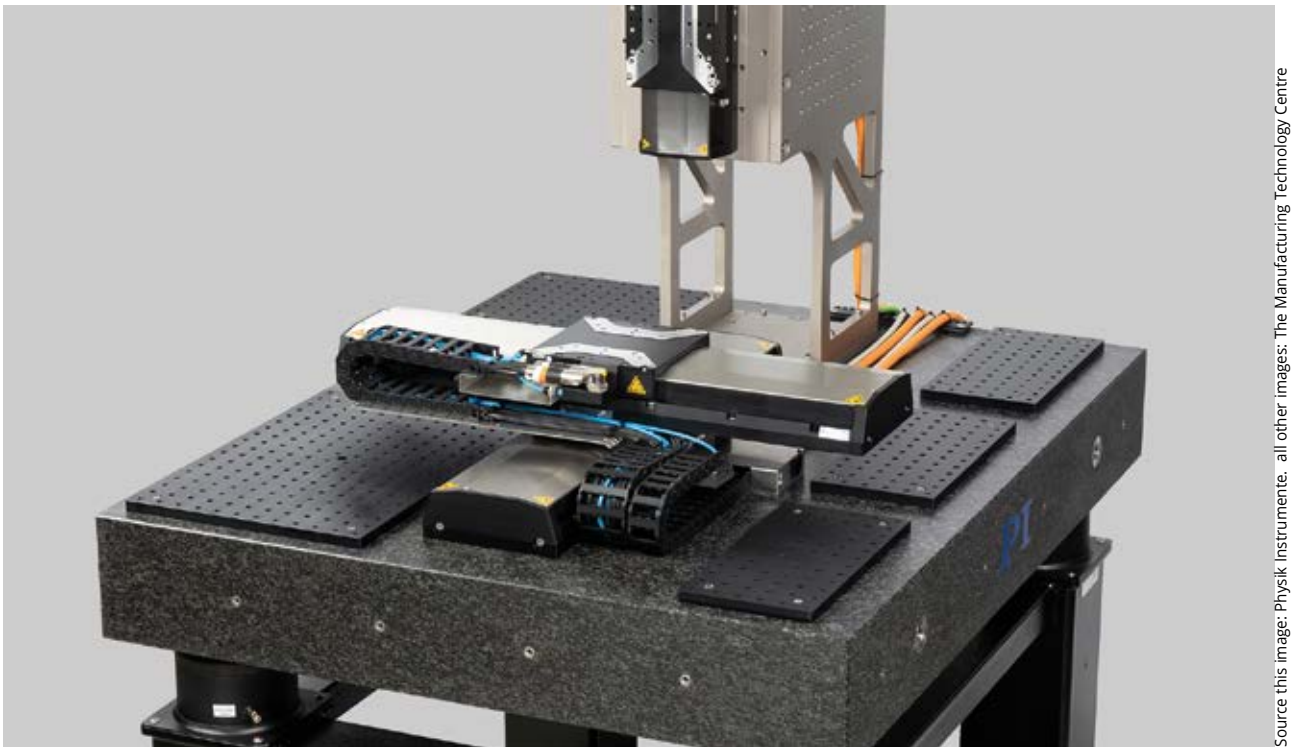
High-speed laser drilling to scale up fuel cells and hydrogen electrolyzers

Fabricating microholes with precise geometry, superior quality, and high production rates

Mitchell Leering, Cliff Jolliffe, and Sundar Marimuthu



Source this image: Physik Instrumente. all other images: The Manufacturing Technology Centre

Scaling up clean hydrogen production using renewable energy is essential for decarbonizing a range of sectors, including transportation, chemicals, and steel, where reducing emissions and achieving net-zero targets have proven to be challenging. Advances in laser-based manufacturing, particularly ultra-high-speed laser drilling, are crucial for economically producing and scaling up hydrogen components, including high-temperature hydrogen electrolyzers (HTHE).

The state-of-the-art in laser drilling for hydrogen electrolyzers is primarily dominated by nanosecond lasers. However, their applicability for drilling materials with thicknesses exceeding 1 mm is limited. Recently, The Manufacturing Technology Centre (MTC), in collaboration with Physik Instrumente (PI), has been focusing on high-speed laser drilling of hydrogen electrolyzer components using high-energy micro-second pulse lasers. By harnessing the high pulse energy and precision of the PI CNC motion stage, the team has achieved the laser drilling of microholes with an average diameter of less than 90 µm at a rate of more than 600 holes/sec. One of the main research challenges in this undertaking was synchronizing the laser pulse with the CNC axis movement to achieve hole drilling positional accuracy of less than five microns.

Fig. 1 Physik Instrumente X-417 configurable three-axis motion system

Introduction

Over the past decade, multiple sectors and industries have committed to achieving a net zero emissions target by 2050. The establishment of low-carbon hydrogen infrastructure is a critical element of curbing global

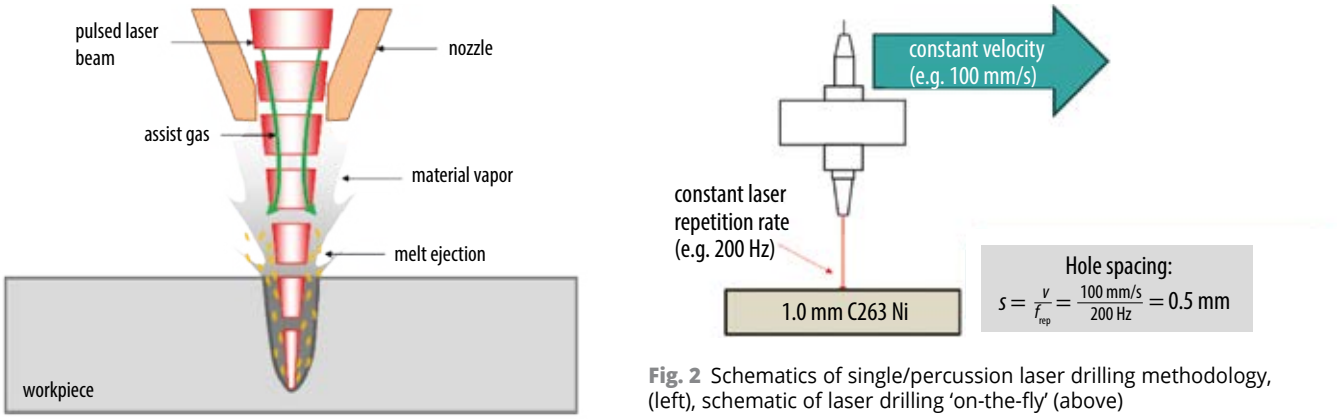


Fig. 2 Schematics of single/percussion laser drilling methodology, (left), schematic of laser drilling 'on-the-fly' (above)

carbon emissions. The generation of affordable green hydrogen stands to make a substantial impact on reducing carbon footprints in industries that are difficult to transition to electrification, like aerospace, automotive, shipping, chemicals, and materials production. Extracting hydrogen gas from water through electrolysis, powered solely by renewable energy sources, presents a clear path towards green hydrogen production. Currently, alkaline electrolysis cells (AEC) and proton exchange membranes (PEM) represent the forefront of electrolysis technologies.

Electrodes made up of porous layers are the key component of hydrogen electrolyzers and fuel cell systems. These layers ensure the critical functionality of the cells as well as provide structural support to the membrane-electrode assembly. Recent research in this field has been directed towards microholes, ranging in size between 30 – 800 µm, to enhance the efficacy of hydrogen electrolyzers. These studies primarily target water management [1], gas bubble saturation [2], and increasing activation sites [4], with laser drilling standing out as a promising enabling technology to manufacture the required porous layers. Porous nickel alloys, a few millimeters thick and resistant to high temperatures, have found widespread application as electrode materials in AEC electrolyzers due to their strong inherent activity [5]. These electrodes typically have forms such as perforated plates [6], meshes [7], and foams [8]. These porous electrodes enhance the efficiency of hydrogen by increasing the active exposed surface area and facilitating the removal of trapped bubbles [9].

The escalating demand for fabricating microholes with precise geometry, superior quality and high production rates in materials of a few millimeters in thickness is increasingly apparent, not just within the hydrogen sector but notably in the aerospace and automotive industries. For instance, microholes (50 – 100 µm in diameter) are used along the leading edges of aircraft wings to reduce drag and increase fuel efficiency [10].

The precise control of heat propagation, material melting, and melt ejection plays a pivotal role in the microhole drilling process and the resulting hole quality, and this is closely linked to the laser pulse duration [11]. To date, short and ultrashort-pulse lasers have been the primary focus of research in this field, due to their capability to produce holes with minimal thermal damage. However, these lasers exhibit low productivity when dealing with the thicker materials (>0.5 mm) that are commonly used across various industrial applications. Achieving much higher productivity becomes imperative for widespread industrialization, and long pulse duration (>µs) laser systems are expected to offer viable productivity levels whilst achieving acceptable hole quality. Previous studies have used single-mode millisecond lasers to drill through 1 mm thick titanium, achieving microhole geometries below 100 µm at industrial scale throughput rates [12].

This study investigated high-speed single pulse microhole drilling (SPMHD) for high-throughput microhole drilling of C263 nickel alloy to support the wider proliferation of hydrogen electrolyzers and fuel cells.

Experimental methodology

The material used in this study was a 1 mm thick commercial Nimonic 263 nickel superalloy. All microhole drilling activities were conducted with an InnoLas system fitted with an IPG 1070 nm

Companies

Physik Instrumente

The PI group, headquartered in Karlsruhe, Germany, is a leading provider of high-precision positioning technology and piezo applications in the industrial automation, semiconductor, photonics, and microscopy and life sciences markets. The basis for this is formed by various drive technologies, proprietary sensors, electronics, and control technology. PI's portfolio ranges from components and subsystems to customized complete solutions. PI operates worldwide and has production, sales and service locations in Europe, North America and Asia.

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Manufacturing Technology Centre (MTC)

The MTC is a research technology organization in the United Kingdom that specializes in digital manufacturing, laser processing, additive manufacturing, automation, and robotics.
The MTC houses some of the most advanced manufacturing equipment in the world alongside market-leading expertise, creating a high-quality environment for the development and demonstration of new technologies on an industrial scale.

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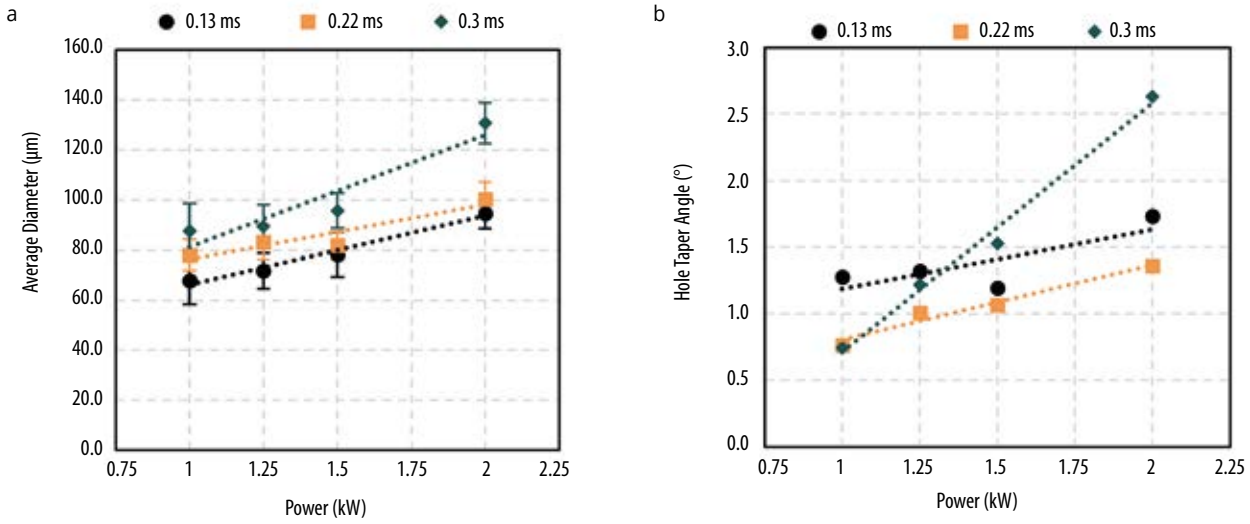

Fig. 3 Influence of peak power and pulse duration on single pulse laser drilling, (a) average hole diameter, (b) hole taper angle

YLR-2000-SM continuous-wave laser source. The system outputs a peak power of 2 kW, with a minimum pulse duration of 10 µs and a modulation rate capable of reaching 50 kHz. A fiber core diameter of 14 µm was coupled with a collimator and focus lens of 150 mm each, yielding a theoretical spot size of 14 µm with a Gaussian shape and an M^2 value of 1.1. The laser focus was positioned on the top surface of the sheet material throughout. All laser drilling was performed perpendicular (90°) to the workpiece surface, with argon assist gas applied coaxially through a 1 mm diameter nozzle, with a gas jet pressure of 4 bar applied directly to the surface. The schematic representation of the drilling process and 'on-the-fly' laser microhole drilling methodology is shown in Fig. 2.

The precise XY motion within the system was provided by Physik Instrumente (PI) linear motor translation stages with direct encoder feedback. Process speeds of a maximum 100 mm/sec were used in the study. The stages provided a positional accuracy of 1 µm. Vertical motion of the laser head was provided by a third axis of a ball-screw-equipped translation stage with a motion brake for safety. This motion system was PI's X-417 configurable system for laser material processing, as shown in Fig. 1.

Results

Fig. 3 illustrates the correlation between peak laser power, pulse duration, average hole diameter, and hole taper angle. A minimum peak power of 1 kW or 0.3 J of energy per pulse was necessary across all tested pulse durations to create holes with sufficient quality in a single shot. Below, the peak power range of 1 kW, the holes were not fully formed with just a single pulse. Typically, the laser would not fully penetrate, or the holes were significantly clogged with remelted material. Fig. 3b shows that the hole taper angle increased with the peak power. All holes exhibited a positive taper, wherein the entrance hole was larger than the exit hole. Notably, the straightest holes across all pulse durations were achieved with a minimum peak power of 1 kW.

Fig. 4 shows the effect of peak power and pulse duration on microhole drilling performance. To understand the repeatability of the drilling process, one hundred holes were tested for each parameter combination. The quality assessment focused predominantly on blockage within the hole caused by either recast/remelted material or the accumulation of dross on the exit hole surface. Increasing both peak power and pulse duration notably enhanced the uniformity of the holes. Notably, a combination of 1 kW and 0.3 ms yielded over 80 % unobstructed holes at drilling rates beyond 400 holes/sec. This configuration emerged as the most favorable, as it resulted in an average hole diameter of approximately 86 µm, the least hole taper angle, and a feasible throughput

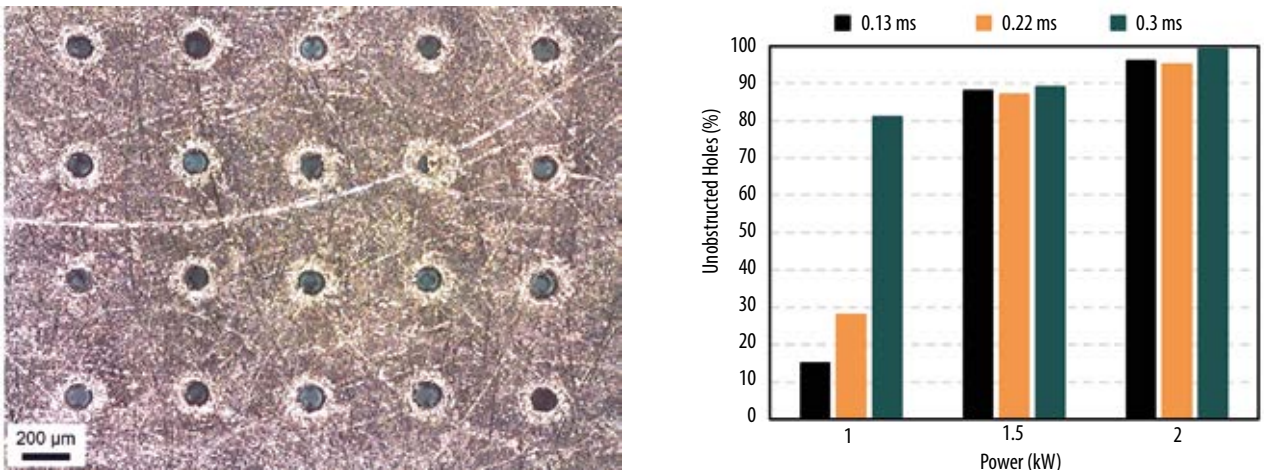

Fig. 4 Influence of peak power and pulse duration on the extent of hole clogging

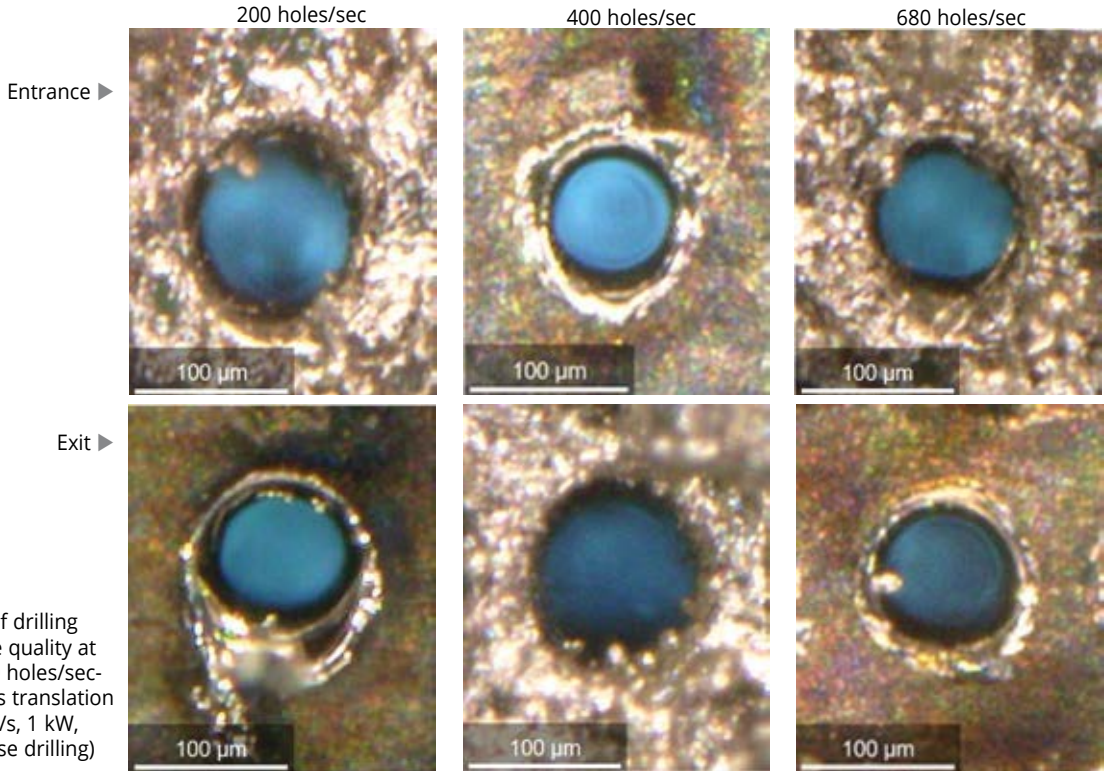

Fig. 5 Influence of drilling rate on microhole quality at 200, 400, and 680 holes/second (constant axis translation speed of 100 mm/s, 1 kW, 0.3 ms, single pulse drilling)

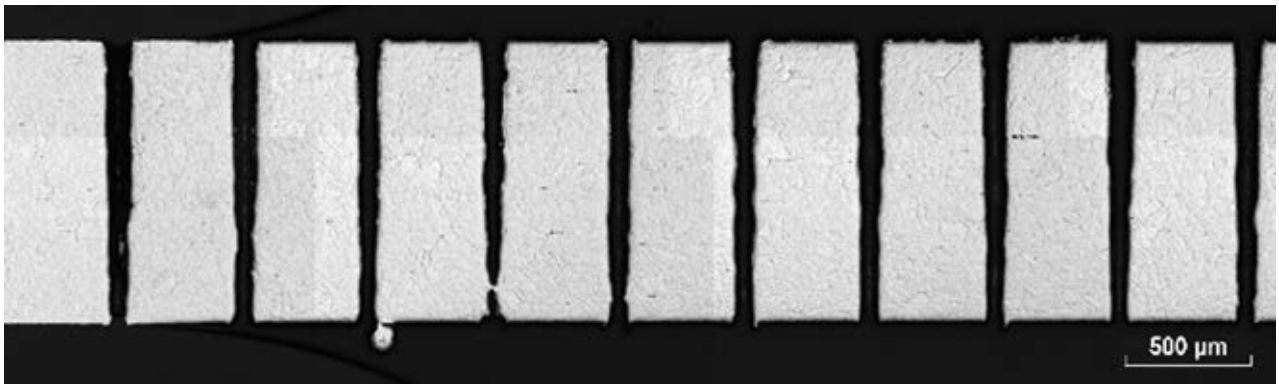

Fig. 6 Optical cross-section of micro-holes drilled at 400 holes/sec

rate, thereby necessitating minimal post-processing of components.

Fig. 5 shows an example of the achieved hole quality (circularity) at various drilling rates. As can be seen in the images, the overall geometric features of the holes (or circularity) were not significantly influenced by the drilling rates, at least for a scanning speed of 100 mm/s. No significant loss of hole circularity was observed with the increase in production rates. Surface spatter occurred throughout and tended to increase due to the reduction in sequential hole spacing as the drilling head of the laser travelled at a constant rate of 100 mm/sec. Small amounts of dross (resolidified material that was ejected from the laser exit surface of the hole) occurred with each drilling setting.

Fig. 6 shows the cross-sectional optical microscopic image (approximately along the centerline) of the laser drilled holes produced with single pulse at 400 holes/sec. A recast layer of approximately 15 µm thick was observed on each side of the holes. Some form of recast layer is expected with this regime of long pulse drilling as the material removal mechanism is dominated by melting and melt ejection. Overall, the holes were found to be consistent in size over the assessed region, with a taper angle of approximately 1 – 2° along the holes' length.

Conclusion

This work demonstrated the capability of high-production rate microsecond laser drilling of microholes in 1 mm thick C263 nickel alloy within a single pulse. The findings indicated that an increase in laser peak power and pulse duration resulted in larger hole diameters and notably decreased instances of hole clogging. This method achieved high-quality microholes of an average diameter of 80 – 90 µm (aspect ratio of 12:1) with minimal taper and at drilling rates of more than 600 holes/sec with no significant loss in hole circularity. The CNC-based single mode fiber laser drilling showcases the potential of laser micro-hole drilling in facilitating high production throughput rates for crucial porous components essential for hydrogen applications.

*

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Cliff Jolliffe has provided precision mechatronics and motion control solutions for the global market for the last 25 years. He heads the strategic marketing push for industrial automation at Physik Instrumente. Cliff holds a PhD from the University of Warwick. The UK government recognizes him as an expert in the field of precision automation, and he has chaired cross-industrial / academic panels who seek to advance technology in manufacturing.

Sundar Marimuthu has fifteen years of experience in laser-based manufacturing and is a principal research engineer at the MTC. His work is on laser subtractive material processing – particularly laser cutting, drilling and machining of metals, composites and ceramics. He has published around sixty journal papers, fifty conference papers and six book chapters. His current research focus is on the development of next-generation laser-based manufacturing processes.

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Epitaxial regrowth

How GaAs is the key to unlocking new semiconductor laser markets

Richard Hogg

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How can design engineers use epitaxial regrowth to enhance semiconductor laser performance and unlock new markets? First, we need to take a closer look at the relatively mature, epitaxial regrowth process for indium phosphide (InP) lasers, commonly used in 5G, datacomms, telecoms and co-located optics applications. Then we can consider gallium arsenide (GaAs), a less mature material system, which suits a multitude of emerging industrial, biomedical imaging, datacomms, and sensing laser applications.

Epitaxial regrowth better meets the need for greater heat dissipation, reduced optical loss, and the ever-increasing demand for photonics integration. It also brings the next-generation device performance necessary for semiconductor lasers of the future. Current InP device manufacturing technology involves multiple epitaxy (additive) and fabrication steps (lithography and subtractive etching) to form the semiconductor laser. This method contrasts with the more basic ridge-laser structures, where one epitaxy step is followed by subtractive etching to form a waveguide, with passivation and isolation to produce electrical contacts (Fig. 1). For InP devices, these epitaxial regrowth processes enable a range of photonic integrated circuit (PIC) building blocks to be produced, such as low loss DFB and DBR sections, gain and passive sections, and buried heterostructures for low optical loss and enhanced heat extraction. InP material systems operate in the 1,200 – 1,700 nm range, whereas GaAs material systems

Company

III-V Epi

III-V Epi provides a range of compound semiconductor wafer foundry services. We specialise in the manufacture of low to medium volume, MBE and MOCVD, III-V, epitaxial structures and overgrowth for compound semiconductor device applications. We offer wafer design, product development and process optimisation along with a complete range of test, metrology and characterisation services. III-V Epi helps its customers to bring new compound semiconductor products to market, as quickly as possible.

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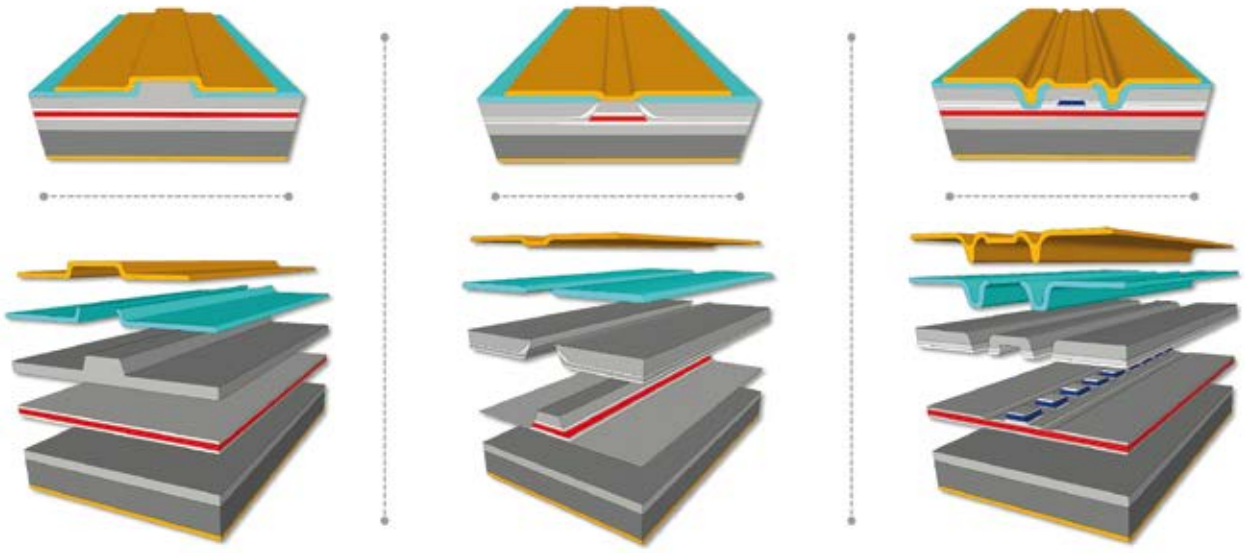

▲**Fig. 1** Example of a simple ridge laser, epitaxially regrown buried heterostructure laser, and epitaxially regrown DFB laser

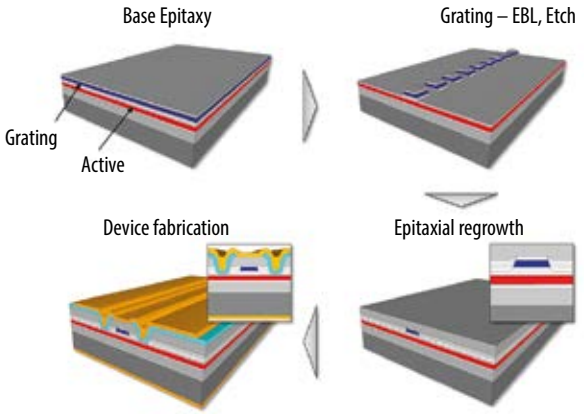

Fig. 2 Distributed feedback (DFB) lasers manufactured by epitaxial regrowth

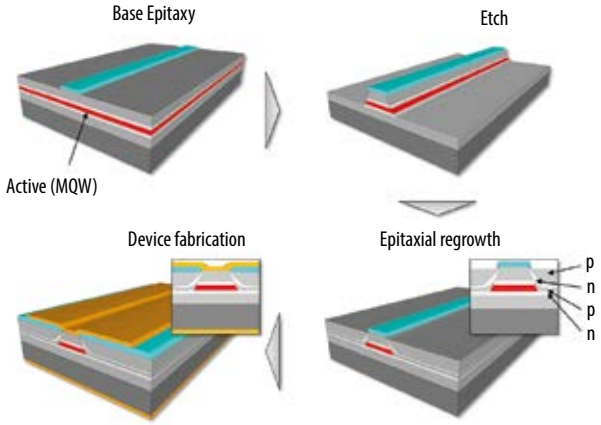

Fig. 3 Epitaxial regrowth steps for buried heterostructure

range from red 650 nm quantum wells to near infrared (NIR) 1,300 nm quantum dots (QDs). This wide range enables new applications in optical datacomms, silicon photonics, biomedical imaging, displays, data storage, and many more. Epitaxial regrowth processes for GaAs are immature in comparison to InP, but to realize next-generation devices it is critically important that performance is extended beyond that of current epitaxy and ridge waveguide technologies.

Distributed feedback (DFB) lasers are typical of a device manufactured by epitaxial regrowth, see Fig. 2. Initially, the lower cladding and active elements (quantum wells) of the laser are epitaxially grown on a substrate. After cleaning and etching, a grating structure is formed in the wafer substrate surface using electron beam lithography and etching to give the distributed feedback (DFB) laser mechanism. This produces the correct period and depth of grating for the optical properties required.

Epitaxial regrowth is usually performed by a metal-organic, chemical vapor deposition (MOCVD) machine, which deposits semiconductor layers onto the substrate surface and grating.

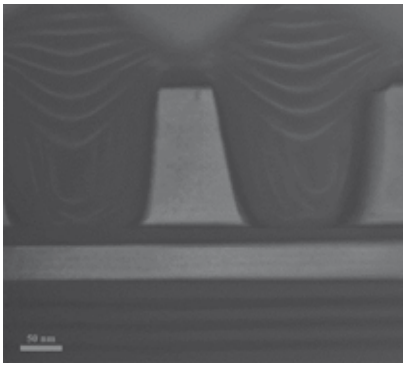

Fig. 4 GaAs-based laser using 'marker' layers to track the regrowth front

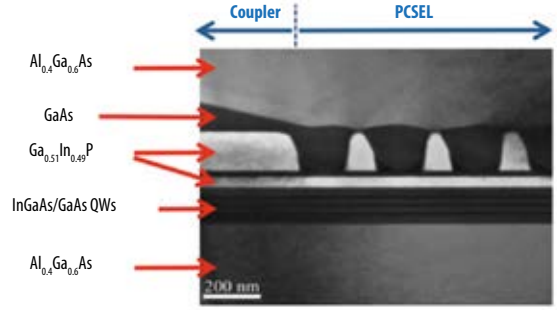

Fig. 5 Novel GaAs-based PIC device

A cladding and cap layer 'sandwiches' the active region with the DFB grating of the laser. This provides optical confinement and guides the light that is emitted from the lasers facet.

A range of parameters are controlled within the process, such as the temperature, the supply of reagents, and the pressure to achieve the correct material properties, crystalline quality, and uniformity across the wafer. Dopants can also be introduced to ensure the required conductivity. From here, the wafer may be processed into an individual laser die in the form of a ridge waveguide laser. Alternatively, the wafer may proceed through other epitaxial regrowth steps to make a buried heterostructure as shown in Fig. 3. Here, optical confinement is much gentler than for a ridge laser, and current confinement is achieved through either a blocking p-n-p-n structure, or by making the overgrown material semi-insulating, such as through doping with iron.

Buried heterostructures allow improved heat extraction and hence greater output power. They also deliver more symmetrical output beams, resulting in lower power loss in the subsequent optical systems and reducing the costs to fiber-package.

III-V Epi develops epitaxial regrowth processes for InP and GaAs materials. The company has developed know-how in the regrowth of GaAs-based components over several years, employing the use of 'marker' layers to track the regrowth front (Fig. 4). Not only does this allow novel GaAs-based PIC devices to be produced (Fig. 5), but it also has capabilities for in-situ etching (cleaning) of the wafer and doping of regrown materials to enable current blocking layers, such as iron-doped indium phosphide lasers (InP:Fe).

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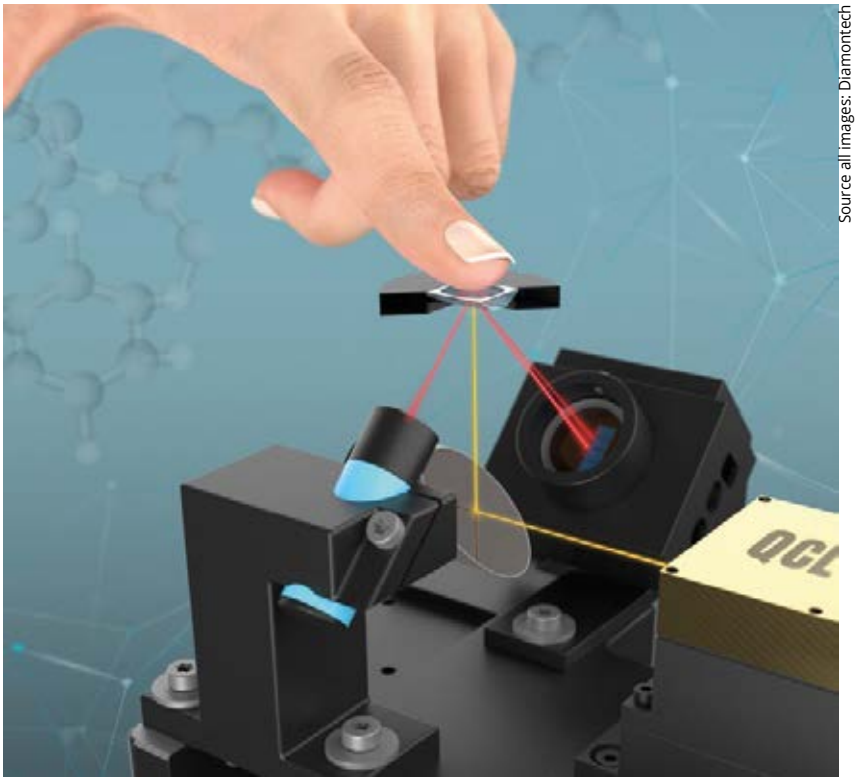
Photonic blood glucose measurement with infrared quantum cascade lasers

A novel non-invasive and pain-free glucometer for diabetes patients

Sergius Janik, Thorsten Lubinski, Michael Kaluza, and Werner Mäntele

Diabetes patients rely on frequent measurement of blood glucose that is presently performed by painful pricking and analysis of a drop of blood. Diamontech has developed a noninvasive technique that targets a prominent mid-infrared signature of glucose. This technique uses quantum cascade lasers and photothermal detection. Clinical validation has proven an accuracy similar to current invasive techniques.



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Worldwide, around 530 million people live with diabetes, with increasing tendency. Reports from the World Health Organization (WHO) and the International Diabetes Foundation (IDF) predict an increase to 600 to 800 million by 2045 [1]. More than 90 % of people with diabetes have type 2 diabetes (T2D), where the cells in the body cannot use insulin adequately. The key drivers for this rise are an ageing population, the lack of physical activity as well as malnutrition and obesity. Diabetes cannot be cured, but it can be managed by strict control of blood glucose and adaptation of food intake, physical activity and medication.

The current method of blood glucose measurement involves pricking a finger and the analysis of a drop of blood by enzyme-based test strips fitting into a glucometer. This intermittent and invasive measurement is painful and unpleasant, and by far not performed frequently enough; it only provides a snapshot of the blood glucose level at the time of the measurement. Continuously measuring glucometers (CGM) have recently been introduced that use a tiny needle in the skin with enzymatic detection of glucose. These minimally invasive devices measure glucose in skin fluid and are very popular among type 1 diabetes (T1D) patients who cannot produce insulin in the pancreas and have to rely on regular insulin injections.

A truly non-invasive, painless and comfortable measurement of glucose would change the life of people with diabetes. Many different attempts have been made to solve this problem, for example by measuring glucose in easily accessible body fluids such as tear fluid, saliva, sweat or urine that might serve as proxies for blood. However, glucose in these proxies either shows little or no correlation with blood glucose, or exhibits a variable and long delay with respect to the ups and downs of blood glucose.

Interstitial fluid (ISF), sometimes also termed skin fluid, appears to be a suitable proxy for blood. ISF is known to everyone as the yellowish liquid that appears on skin upon shallow scratches and, in a similar form, as the liquid in blisters. Compared to blood, it is a relatively simple matrix essentially composed of water, ions, the protein albumin, phosphate and glucose. ISF contains around 85 – 90 % of the glucose concentration in blood, and the lag time between blood glucose variations and ISF glucose variations is low, on average five to ten minutes. ISF is found in skin layers immediately underneath the top layer of the epidermis, the stratum corneum, at a minimum depth of 20 – 100 µm, depending on the skin site. A photonic glucose sensor that obtains spectral information from these deeper layers can measure ISF glucose that is representative of blood glucose.

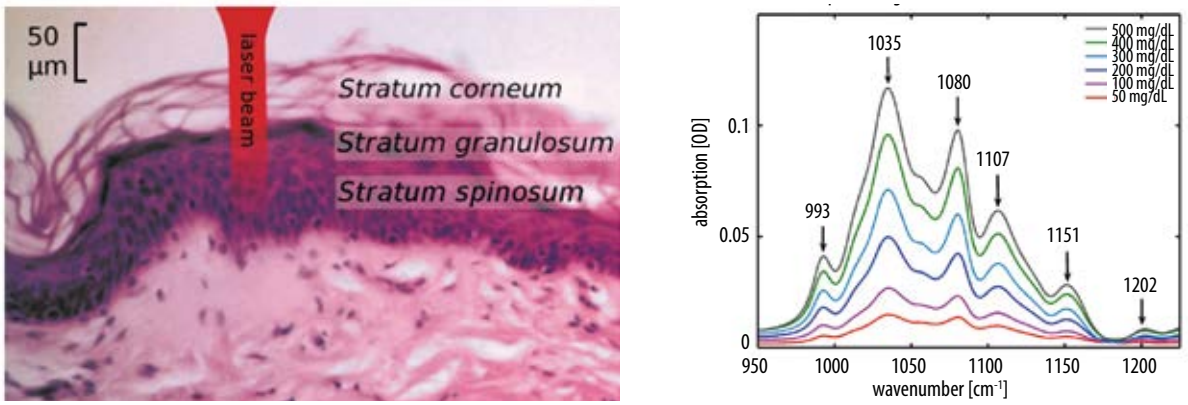

Fig. 1 Left: Schematic representation of the epidermis layers (based on a histology sample) with a laser beam attenuated. Right: Infrared spectra of glucose at concentrations relevant for blood glucose (50 – 500 mg/dL)

A photonic solution for non-invasive glucose measurement

Diamontech has developed a photonic technique based on infrared (IR) quantum cascade lasers (QCL) and photothermal detection [2, 3]. This technique targets a glucose signature in the mid-infrared, in the spectral range of approximately 8 – 11 µm caused by the vibrations of the glucose molecule (mainly –C-O- stretching and –O-H bending modes). This signature with clear maxima and minima (see Fig. 1) is highly specific for glucose in terms of a 'glucose fingerprint' that can be used to distinguish glucose from other molecules in the skin, and thus warrants the specificity required for a reliable glucose sensor.

The challenge of a photonic glucose measurement in skin is the measurement of the glucose response upon selective infrared excitation of vibrational modes of glucose. The penetration depth of infrared radiation into skin is around 60 – 100 µm (mainly dependent on the water content), deep enough to reach the ISF but not deep enough to reach the blood vessels or for a conventional transmission measurement.

Photothermal detection of glucose in skin

In order to solve this problem, Diamontech has developed a photothermal detection technology (Fig. 2) that is sensitive and selective enough for glucose sensing and can be realized into devices that have a comfortable form factor suitable for everyday use.

The measurement principle is based on the small amount of heat deposited into the tissue after vibrational excitation of glucose molecules from the vibrational ground state to the first excited state (v_0 to v_1), immediately followed by thermal relaxation. Consequently, glucose-containing layers in skin experience a tiny warming (by some millikelvin, strictly proportional to the glucose concentration). The heat gradient spreads out from glucose-containing layers to the skin surface. While the skin surface is in contact with an IR-transparent internal reflection element (IRE), the heat traveling to this ZnS crystal changes its optical properties, such as the refractive index n. As a consequence of excitation of the skin with the pulsed mid-IR pump beam from the quantum cascade laser, a transient thermal lens is formed in the IRE. This thermal lens can be compared to the one that forms in the air on top of an asphalt layer in sunlight, leading to a mirage effect. A second laser beam (termed 'probe beam') in the red or NIR spectral region is used to read out this thermal lens. The deflection of the probe laser beam (the photothermal signal) is measured with a simple position-sensitive silicon photodiode (PSD). Deflection depends on the mid-IR excitation power and the glucose concentration. The glucose concentration is analyzed by either tuning the QCL through the entire glucose fingerprint range or recording the photothermal signal at selected mid-IR wavelengths in that range. The selectivity of this technique relies on the spectral fingerprint of glucose and its sensitivity on the proprietary photothermal detection.

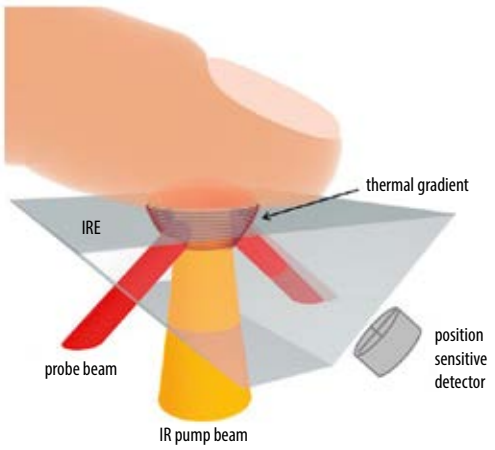

Fig. 2 Principle of IRE-supported photothermal detection of glucose in skin

Company

DiaMonTech AG

DiaMonTech (Diabetes Monontoring Technology) was co-founded in 2015 by Thorsten Lubinski and Werner Mäntele to develop non-invasive glucose monitoring for diabetes patients. Based in Berlin, the company employs more than twenty experts in laser physics, optics, electronics and software as well as experts in regulatory affairs and marketing. Based on the R&D work of one of the founders, Prof Mäntele, DiaMonTech has created a laser-based sensing technology with applications for non-invasive glucose-monitoring, wellness applications and bio-process monitoring. DiaMonTech owns 25+ patents and has filed more than seventy patents.

www.diamontech.de

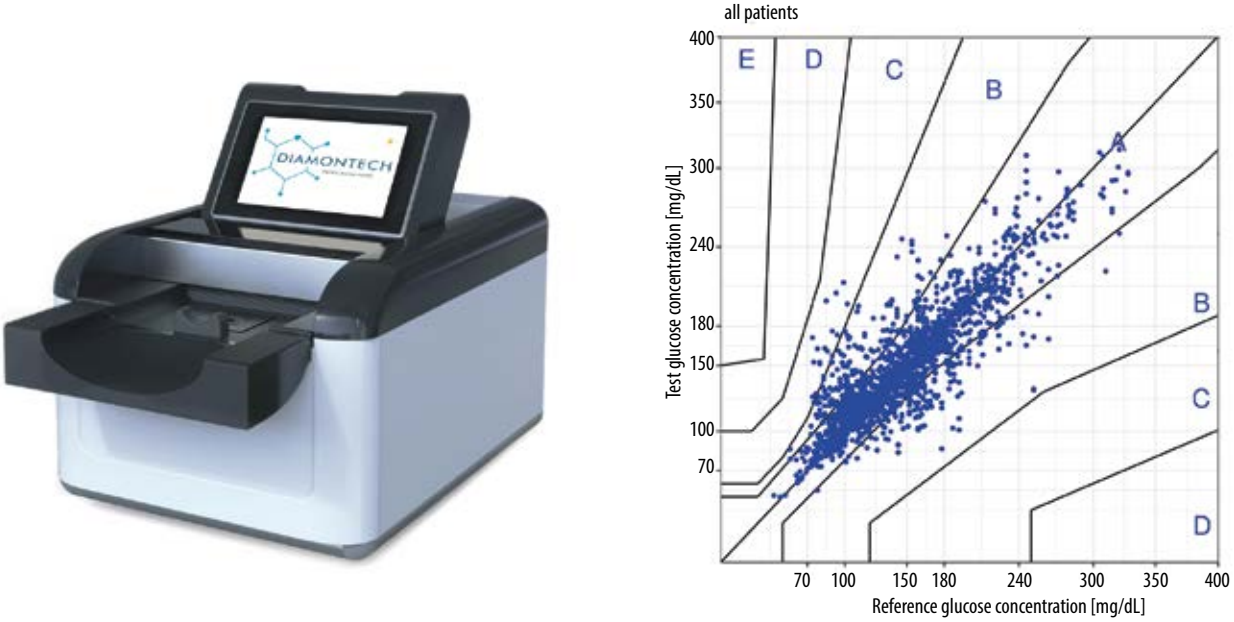

Fig. 3 Left: Diamontech's CE-certified non-invasive 'D-Base' glucometer. Right: Clinical validation in a study involving 100 healthy and diabetic volunteers

From the optical table to device prototypes

Once the proof-of-principle had been shown, Diamontech developed a shoebox-sized tabletop device ('D-Base', see Fig. 3) for clinical validation.

The D-Base incorporates an external-cavity tunable QCL to scan the entire glucose fingerprint range in the mid-IR with photothermal detection of the glucose response. D-Base is a multi-user device with RFID-based user identification, stored user-specific calibration, and data logging. The user places the wrist on the IRE sensor crystal and keeps it still for about twenty to thirty seconds. After the measurement has been taken, the glucose value is shown to the user on the device display.

A first validation of the technique has been performed in a clinical study with 100 volunteers, with about half of them being type 1 and type 2 diabetes patients, and the other half were healthy subjects. All volunteers were subjected to a 3-hour glucose correlation test with a non-invasive measurement and an invasive reference measurement with a clinical glucometer for comparison, both simultaneously taken every 5 minutes. This resulted in a data set of about 2,000 data pairs in the blood glucose range of 50 mg/dL (hypoglycemic) to about 350 mg/dL (hyperglycemic) [4].

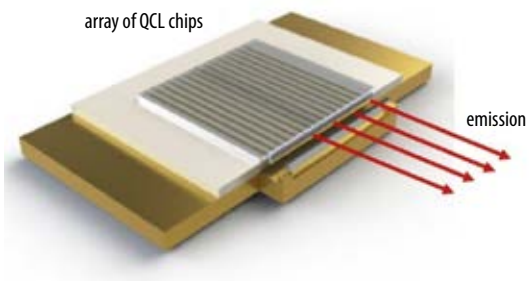

Fig. 4 Schematic graphic of a miniaturized multi-emitter QCL array

The data-scientific evaluation was made retrospectively with a linear set of multivariate algorithms. This data set can be visualized in a consensus error grid (Fig. 3, right) where invasive/non-invasive data are plotted against each other. More than 99.1 % of the data fall in zones A and B, and only 0.9 % in zone C. No data are in zones D and E where the error of a measurement would present a risk for the user. Overall, this cross-validation has revealed an accuracy that corresponds to that of early minimally invasive glucometers. Moreover, it has shown that a delay between blood glucose and ISF glucose, if at all, is in the range of the measuring intervals, i.e. five minutes.

The learnings from the study have also contributed to several improvements in the stability, sensitivity and data evaluation of the device. The stability of the device outside a lab environment had to be improved through better thermal management of the components as some signal-drifts were noticed. Additionally, the ergonomics for more comfortable measuring of the correct skin site had to be improved. Algorithms for detection of outliers, checking for good skin contact or contamination (e.g., through skin lotion or dirt) and AI-driven spectral-feature detection were implemented based on the lessons learned from the study.

Ongoing clinical studies of this novel method are now being performed with the state-of-the-art device in order to determine the necessary calibration procedures and the long-term stability in a foresighted way. Secondly, the continuous improvements of hardware, software and evaluation algorithms leading to even better sensitivity, stability and calibration robustness are being thoroughly studied and measured. At present, it appears that a user will have to perform an initial calibration with a pricking device and then use the non-invasive method for days or weeks, with regular recalibrations from time to time being necessary to account for altered skin properties.

The challenge of further miniaturization

Based on the experience and learnings with the D-Base, Diamontech has further miniaturized the glucometer towards a smartphone-sized handheld device (D-Pocket) that is presently being finalized (Fig. 5). It is based on the same photothermal deflection technology as the D-Base but uses a miniaturized QCL array emitting discrete wavelengths in the glucose fingerprint range. A QCL array with up to sixteen multiplexed emitters, with each one set to a relevant IR wavelength, does not require a moving grating as compared to an

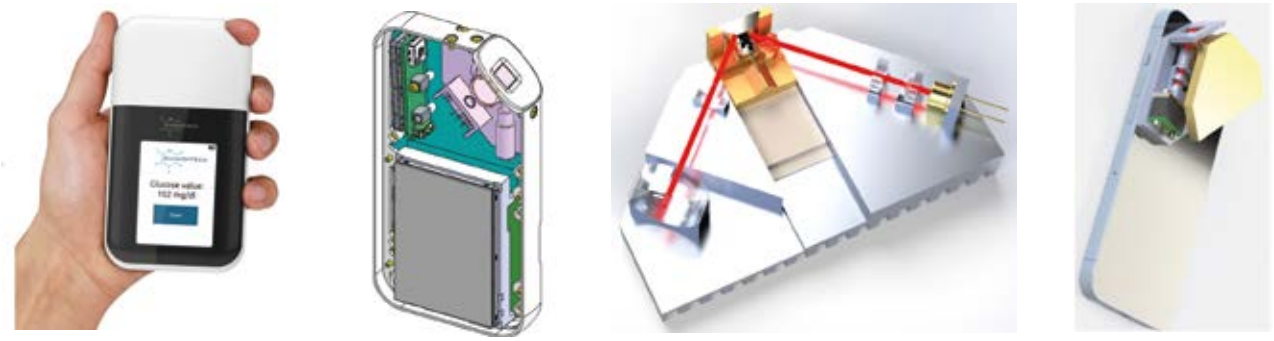

Fig. 5 Diamontech's handheld D-Pocket glucometer (under development); from left to right: top view of display and measuring site on the upper left side; cutaway view of optics and electronics; schematic display of QCL excitation and photothermal detection, and display of the complete optical unit on a smartphone for size comparison

external-cavity tunable QCL. It can be built to the size of a fingernail and is scalable in quantity. The required laser power for each emitter is in the range of a few milliwatts, which allows passive cooling (see Fig. 4)

Besides the miniaturization of the QCL, the sensing unit has been developed further into a small monolithic and optimized form, implementing all the knowledge gained from its 'big brother', the D-Base. The small form-factor allows the use of non-invasive measurement within a compact handheld device (cf. Fig. 5).

The improvement of the measurement principle allows the measuring time to be decreased to approximately fifteen seconds. The D-Pocket works autonomously but can communicate with a companion app developed by Diamontech. The app is a diabetes diary with input from a D-pocket or from invasive measurements. After completion of the handheld D-pocket development, a clinical validation period and certification as a medical product will follow. The D-Pocket will be the personal companion of the diabetes patient and will allow frequent reagent- and pain-free blood glucose measurement to improve the quality of life.

Is further miniaturization possible?

The key component of QCL-based photothermal glucose measurement is the quantum cascade laser. QCL structures can be fabricated in the sub-mm range and grouped into arrays of just a few square millimeters. Instead of photothermal detection by beam deflection (Fig. 2), interferometric techniques are currently under investigation to detect the small amount of heat generated upon glucose vibrational excitation. The interferometric sensing unit can be manufactured as a photonics-integrated circuit (PIC) that will significantly reduce the volumetric footprint of the sensing portion of the device. A PIC-based sensing unit will also be more stable and less prone to noise sources. Combined with the next generation of compact QCLs, an application as a CGM-device inside a wristwatch comes into reach.

Decades of research have made a non-invasive glucose monitor in a wearable form factor possible that improves the life of people with diabetes and offers multiple other wellness applications, such as increasing athletic performance or supporting weight loss programs by continuously monitoring blood glucose levels without pricking.

*

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[1] International Diabetes Foundation: https://diabetesatlas.org/
[2] *M. A. Pleitez* et al., Analyst **140** (2015), 483-488
[3] *O. Hertzberg* et al., Analyst **142** (2017), 495-502
[4] *T. Lubinski* et al., Journal of Diabetes Science and Technology **15** (2021), 6-10

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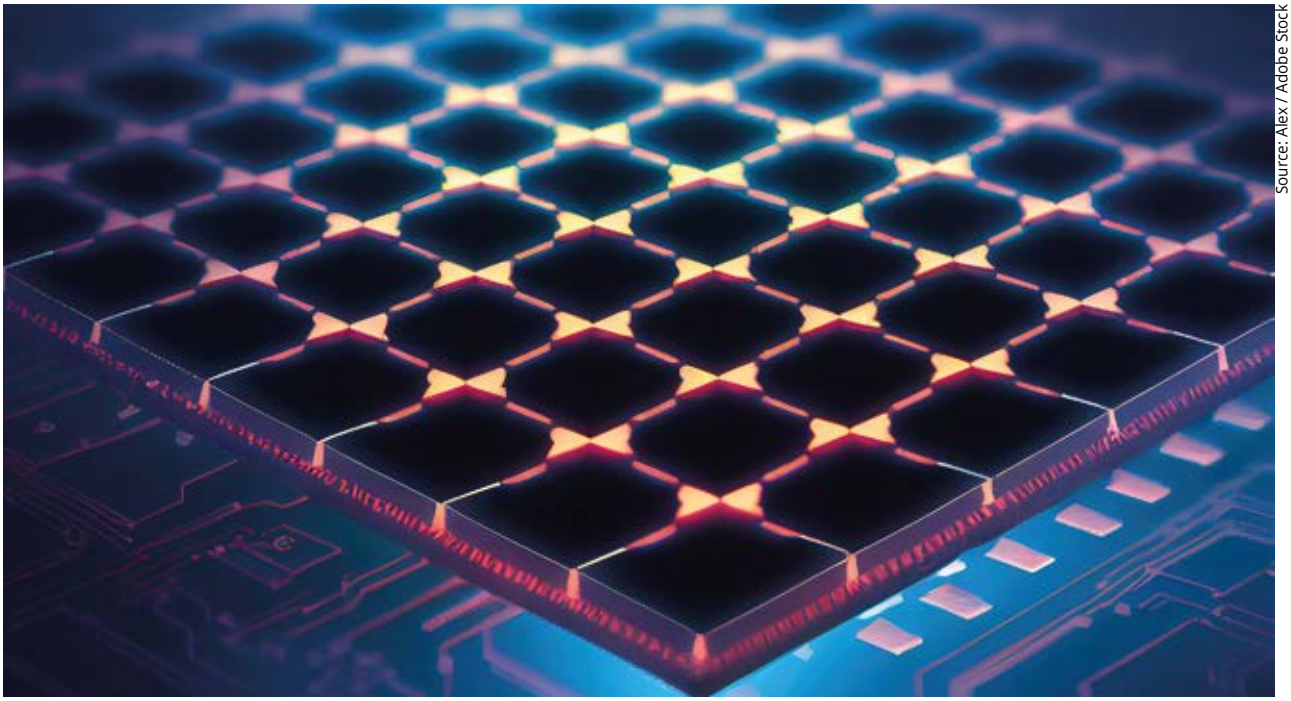
Advancements in hybrid photonics integration

Unleashing this technology's potential in Europe

Ivan Nikitskiy



Source: Alex / Adobe Stock

This article examines the latest developments in hybrid photonics integration, with a focus on the European ecosystem. It discusses the transition from low-cost prototyping of photonic integrated circuits to the pilot line production of photonic chips.

Emphasizing performance and affordability of silicon photonics, the hybrid approach combines the strengths of silicon nitride and indium phosphide material platforms. The use of innovative techniques for hybrid integration like micro transfer printing are explored here along with effective test, assembly, and packaging approaches. The reported results from several key players in the European ecosystem of integrated photonics promise an essential improvement in the performance of transceivers, sensors, and several other technologies in the near future.

Jeppix

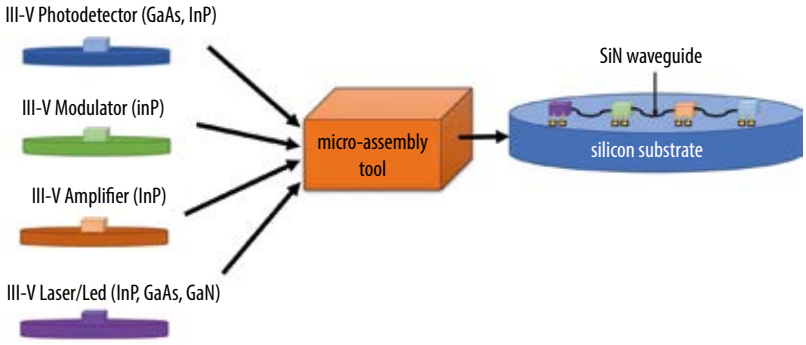
One of the key European initiatives to bring together the European photonic integrated circuit (PIC) supply chain is the Jeppix consortium. Most recently, partners of this European consortium have been looking at driving industrialization with pilot line initiatives for high performance PIC technologies. Previously, they had created MPW services for low-cost PIC prototyping for orientating the supply chain, but more recently, they have been scaling up in relation to pilot line services that bridge the gap from prototype through to qualified production. The technology is both premium in terms of performance and also affordable. For indium phosphide technologies, there are the advantages of having native active building blocks, powerful process design kits and high-speed components. In addition, with silicon nitride comes ultralow waveguide losses and low-loss coupling into fibers, In parallel, together with other partners, they are looking at engagement and co-financing models for new entrants to the PIC industry.

Jeppix partners have been looking at hybrid and heterogeneous integration, as well as electronic integration with photonic circuits. Research project highlights include integrating a full wafer of CMOS electronics with a membrane on top with indium phosphide circuits with lasers and receivers and arrayed waveguides. In this way, they will provide the building blocks for drivers for all the electronic components required for sensor and transceiver technology, which is helping to drive up speed and drive down energy needs. There are also nanophotonic programs that are now available as an MPW prototyping service to provide all the functional indium phosphide components such as lasers, amplifiers and photodetectors together

with slot technology, ring resonators, and service grating couplers.

With regard to the future, Jeppix is moving towards three-dimensional integration with layers of photonics, electronics and potentially MEMS and other sensor technology. One of the technologies they see as being particularly topical is micro transfer printing. This involves taking high-performance indium phosphide PICs and using micro transfer printing techniques with laser and amplifier coupons and arrays to print very high-performance chips onto silicon photonics. This is a particularly important program for Jeppix partners, known as the INSPIRE Program, which is now entering its final phase. They hope to see this technology for prototyping and product development becoming available in the next few years through the PhotonixFAB pilot line. The advantages are that the indium phosphide components provide very good electrical performance and efficiency for modulator lasers while the silicon nitride gives a very low loss that enables long delay lines or super low loss cavities.

Jeppix are very much about access to technology. Once a product or a prototype is being developed within the pilot line program, Jeppix provides a framework for testing chips in software, integrating measurement techniques and doing virtual testing. Therefore, by developing some of the process design kit capabilities and open standards, they are able to create chip description files and measurement description files, and thereby give assurance that the chips are testable using automated testing.



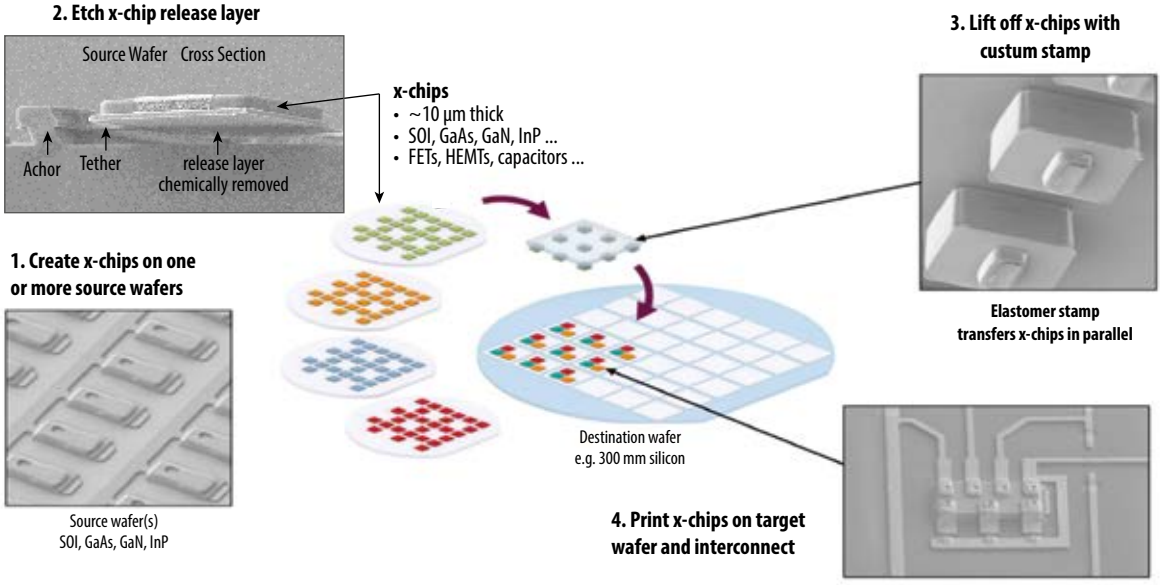
Schematic of hybrid photonic integration (Source: X-Celeprint)

Smart Photonics

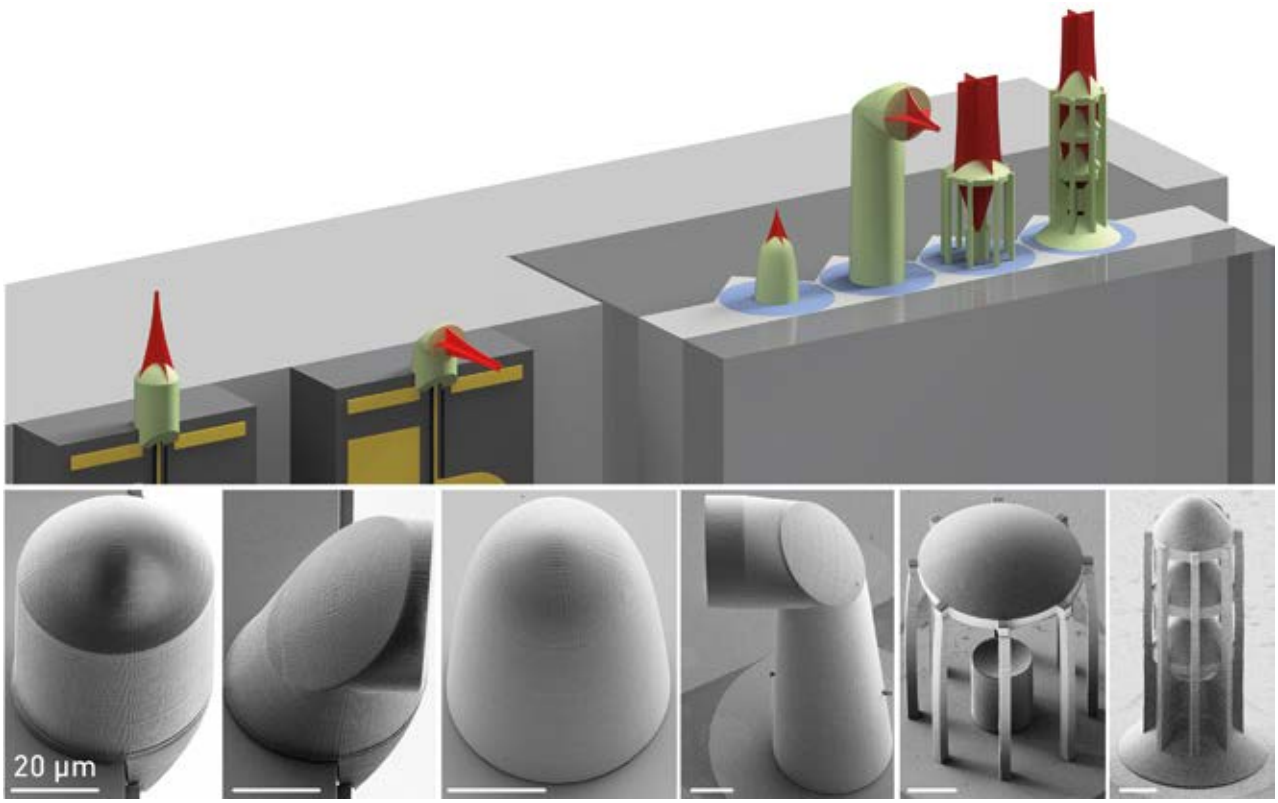
Headquartered in Eindhoven, Smart Photonics is a pure-play foundry providing manufacturing services for InP wafers based on customers' designs and it has the processes and capacity to support customers from prototype to volume MPW services. Smart Photonics' aim is to simplify complexity for their customers by providing a process design kit (PDK) toolbox for passive waveguides, waveguide gratings, high-speed phase modulators, lasers, amplifiers, and photodiode arrays. The combination of such elements allows chips to be fabricated mostly for datacom and sensing applications. Their process expertise and building block performance enable customers to achieve faster prototyping and time to market.

For Smart Photonics, the key to success is InP, the only material suitable for lasers and amplifiers. InP and the butt-joint integration approach allow no compromise between active and passive components. InP also enables actives like lasers and amplifiers, high-speed phase and amplitude modulation, and passives such as connecting waveguides and splitters, etc. Furthermore, InP enables full on-wafer electrical testing and low-cost integrated circuits.

Smart Photonics recently established an internal program for hybrid integration based on transfer printing technology, which allows the hybrid integration of InP coupons to other photonics platforms like silicon photonics and nitride. This program is part of the PhotonixFab project, a full EU-based photonics device value chain with industrial manufacturing capabilities and a pathway to high-volume manufacturing. The aim of this project is to create two pilot lines of hybrid platforms for commercial goals. Smart Photonics is also part of the AMBROSIA consortium, an EU project aiming to develop a multiplexed plasmo-photonic biosensing platform for rapid and intelligent sepsis diagnosis at the point of care, as well as the INSPIRE project (also EU funded) where the technology will be validated by three use cases: a distributed fiber-sensing readout unit, a microwave photonic radio-frequency



Overview of the micro transfer printing process used in an industrial setting (Source: X-Celeprint)



A selection of beam-shaping elements at chip and fiber facets (Source: Vanguard Automation)

pulse generator, and a datacenter switch fabric.

Phix Photonics Assembly

Founded in 2017 and based in Enschede in the Netherlands, Phix Photonics Assembly is an independent, pure play packaging facility that supplies PIC and MEMS based components and modules in scalable production volumes. They support all PIC platforms including silicon photonics, silicon nitride, indium phosphide, and they can help optimize customers' PIC design and module BOM for smooth scale-up to large manufacturing volumes. They are specialized in hybrid PIC assembly, fiber attachment, and ultrahigh frequency electronics interfacing.

VPI Photonics

Drawing on over 25 years of experience, this company is a market leader in photonic design automation solutions. They offer a comprehensive suite of simulation solutions from network-level link engineering down to the device-level, with an optical transmission system and component design in between.

With respect to photonics integration, they provide PIC design solutions and PDK libraries to enable the design of hybrid PICs. Their unique offering enables the design of waveguide-based devices for use as building blocks, together with PDK elements from various foundries and materials for simulation. The associated layouts are also automatically exported into third-party software tools for fabrication. In addition, the PIC design can be validated at the system level to understand how the PIC will affect the overall transmission system performance. Finally, there is the ability to co-simulate the optical circuit with an electronic design. Once these other structures are known, the complete circuits can be designed, optimized, and then validated to determine how they behave in the whole network.

However, as they point out, a major challenge in supporting such functionality is the lack of standardization in photonics, starting with very basic data formats and fundamental building block descriptions up to high-level definitions of how multiple foundry platform chips should be combined. VPI Photonics is trying to address these challenges by committing to standardization initiatives and providing a custom PDK framework, allowing users to integrate their building blocks into existing PDK infrastructure and build new PDK libraries.

Vanguard Automation

The company based in Karlsruhe, Germany, offers automated photonics assembly processes and machines for 3D nanoprinting in the field of photonic multichip integration and packaging. Although PICs are already ubiquitous in data and telecom applications and continue to proliferate in spaces such as FMCW lidar and quantum applications, building photonic systems out of discrete components at volume still represents technical and commercial challenges. Packaging and assembly challenges arise from the necessity to integrate various optical components from different material platforms and with vastly different mode fields. Viable solutions for industrial volume production must provide scalable low-loss coupling between photonic components of arbitrary materials and mode fields while fulfilling industrial reliability specifications and satisfying cost considerations.

To address these challenges, Vanguard Automation has developed process technology based on 3D laser lithography, namely photonic wire bonds (PWBs) and facet-attached microlenses (FAMLs). Originally inspired by electric wire bonding, PWBs create low-loss, 3D free-form connections between optical components without requiring active alignment or additional external optical components to improve mode matching. This process is inherently automatable and provides a high degree of design-flexibility. 3D nano-printing

has also been used for several years to fabricate FAMLs on optical chips and fibers, enabling low-loss coupling with relaxed alignment tolerances, and for wafer-level probing of optical devices. FAMLs also integrate 'smoothly' into an existing process since they can be printed at wafer or die-level prior to 'pick-and-place'.

With regard to hybrid integration, Vanguard Automation's technology can be used on various material platforms, such as silicon, silicon nitride, indium phosphide, and lithium niobate to advance the concept. Additionally, to overcome the problems faced by chipmakers in creating complex spot size converters for various applications to facilitate coupling to their chips, Vanguard's technology can work with simple inverse tapered edge couplers built by stepper lithography.

X-Celeprint

Founded in 2013 and headquartered in Cork in Ireland, X-Celeprint is an international leader in micro transfer printing, serving clients in Europe, North America, and the Asia Pacific. Their mission is to empower chip manufacturers to achieve heterogeneous integration. X-Celeprint's core technology is micro transfer printing (MTP), which is a wafer-scale-compatible pick and place technology that allows the parallel transfer of diverse microcomponents onto different substrates by exploiting the viscoelastic property of PDMS stamps. Their business model is the licensing of the technology itself together with the development of micro transfer printing solutions for specific applications, and the provision of MTP prototype services.

The benefits of this process are dense component arrays and pre/post fabrication of the starting wafer, which gives good source wafer exploitation and a known good die. Additionally, transfer is scalable and parallel, and chips can be fabricated from different wafers and integrated onto the same substrate, which provides high throughput, flexibility and a mix-and-match methodology. Finally, printing is done with the passive alignment at submicrometer accuracy, providing high throughput and enabling integration of III-V on silicon photonics.

With specific regard to III-V MTP onto Si, suitable substrates also include glass, SiO_2, GaAs, InP–SOI, and SiN, while interfaces may be adhesive layers as well as adhesive-less to engineered layers. A variety of light coupling configurations are available, i.e., edge, evanescent, and grating.

Thales

This French multinational based in Paris, designs, develops, and manufactures electrical systems as well as devices and equipment for the aerospace, defense, transportation and security sectors. Being a good example of a potential user of integrated photonics technology and a member of the INSPIRE Program consortium, Thales is studying micro-transfer printed III-V on silicon nitride for the application of distributed acoustic sensing (DAS), which is commonly used in structural health monitoring of buildings, roads, pipelines, as well as ocean monitoring and more.

The DAS setup relies on optical frequency domain reflectometry (OFDR), which enables the measurement of local external perturbations along a fiber with a frequency-modulated laser (FMCW). The results obtained have shown that the integration of InP on silicon nitride allowed the use of a very narrow line width tunable laser that can provide mm range resolution for acoustic sensing and functionality that cannot be obtained with other means. Their future projects will also include the integration of a sensor fiber readout and the integration of a frequency-shifting loop on a photonic integrated circuit.

Conclusion

In this this article we have looked at some of the recent advancements in hybrid photonics integration, performed within the European PIC supply chain. Challenges remain. The first is the lack of standardization in photonics, from very basic data formats and fundamental building block descriptions up to high-level definitions of how multiple foundry platform chips should be integrated. Related to this is a second challenge, i.e., the problems of integrating various optical components from different material platforms and with vastly different mode fields. Specifically, viable solutions for industrial volume production must provide scalable low-loss coupling between photonic components of arbitrary materials and mode fields while fulfilling industrial reliability specifications and satisfying cost considerations.

However, the European PIC industry is successfully addressing these challenges. Regarding standardization, there is a commitment to standardization initiatives and the provision of a custom PDK framework, allowing users to integrate their building blocks into existing PDK infrastructure and to build new PDK libraries. Regarding the second challenge, companies are developing process technology based on 3D laser lithography, namely, photonic wire bonds and facet-attached microlenses that can be used on various material platforms, such as silicon, silicon nitride, indium phosphide, and lithium niobate. Similarly, micro transfer printing can enable chip manufacturers to achieve heterogeneous integration, as it is a wafer scale compatible pick-and-place technology that allows the parallel transfer of diverse microcomponents onto different substrates. Altogether, there is a strong technology push in this field, and all it needs to take off is to find a similar market pull. Overall, a compelling technological momentum is evident in this field; all that remains for it to truly thrive is the discovery of a matching market demand.

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Source: Nexus Media Events

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January 27 – February 01, 2024
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https://spie.org/pw

February 21 – 22, 2024
TOP Conference 2024
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https://photoptics.scitevents.org

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Singapore
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Laser applications boost battery manufacturing efficiency

Review: EPIC Meeting on Laser Applications along Battery Manufacturing Process at ARENA2036

The growing demand for modern electric vehicles has necessitated the development of more efficient batteries with enhanced performance. Laser cutting and welding techniques are already integrated into battery production lines.

Source: EPIC

Group picture at the EPIC Meeting at ARENA2036

Laser cutting finds applications in various battery components, including separators and electrodes. Laser welding has evolved to meet the requirements of minimal heat-affected zones, precise control of penetration depth, high processing speed, and the welding of dissimilar metals, thanks to the development of new laser sources with the right parameters.

During a two-day meeting hosted by the University of Stuttgart at the cutting-edge research campus ARENA2036, a panel of experts discussed the latest developments, new applications, and market trends. Twenty speakers representing the entire supply chain, including automotive companies, battery manufacturers, process monitoring firms, and laser manufacturers.

In the domain of cathode/anode manufacturing for example, Precitec's sensors allow the inline and contactless measurement of critical quality criteria in cell production. Meanwhile, Trumpf highlighted the challenges of laser cutting of battery foils due to the complexity of foil materials and electrode designs.

Regarding battery cell manufacturing on the other hand, Ennovasense introduced its single-sided sensor for measuring the thickness of various types and geometries of coatings on bipolar plates. The lightweight and thermally conductive nature of aluminum makes it advantageous for e-mobility applications, and Civan Lasers has developed dynamic laser beam welding for high-strength aluminum battery housings. An improved cycle time is essential for the electric vehicle business model. Which is why Scanlab developed on-the-fly welding for 1D linear stages to enhance battery manufacturing efficiency.

www.epic-assoc.com

A trade fair impressed the industry

Review: Blechexpo / Schweisstec, 7 – 10 November 2023, Stuttgart, Germany

The 16th Blechexpo, international trade fair for sheet metal working, held jointly with the 9th Schweisstec international trade fair for joining technology, was a success. The 40,103 trade visitors were delighted by 1,256 exhibitors from 38 countries, nine fully booked halls and an unrivalled, packed programme of events. The Best Award 2023 brought smiles to the faces of the many worthy winners.

The trade fair duo was an international showcase for innovation and customer benefit in sheet metal and metal processing. The central themes revolved around automation, sustainability, energy efficiency, skilled labor shortage, and customer service. The trade show offered solutions for more efficient production, better material utilization, and higher part quality, while simultaneously reducing energy consumption and CO_2 emissions. With the goal of making steel production and sheet metal processing more sustainable, Blechexpo / Schweisstec provided significant impetus and demonstrated that even small businesses can successfully embrace automation. The winners of the Best Award 2023 impressively showcased what is possible with technical innovation and inventiveness.

The majority of foreign exhibitors in Stuttgart came from Italy, Switzerland, Turkey, China and the Benelux countries. The themes of the Blechexpo / Schweisstec fairs and solutions for current challenges presented there are disseminated worldwide and have a global impact. "It was clear that many companies are currently dedicating themselves to solving the same problems because this is the only way to ensure the future viability and competitiveness of our industry," points out Georg Knauer, project manager at PE Schall. "These include further automation, especially in the periphery, higher productivity, improving part quality still further, eliminating scrap, saving energy, compensating for the shortage of skilled workers, employee protection and customer service. These are issues that affect every company," says Knauer, summarizing the current topics. "The solutions and strategies we saw at the trade fair are laying the foundations for greater sustainability. The sheet metal industry also has long-term goals for becoming environmentally friendly and visitors to the trade fair could see at first hand which steps have been taken towards achieving this goal."

Source: P.E. Schall

Visitors and booths of Blechexpo / Schweisstech 2023

The next Blechexpo and Schweisstec take place from 4 – 7 November 2025 in Stuttgart, Germany.

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

"A successful premiere in Jena"

Review: W3+ Fair, 29 – 30 November 2023, Jena, Germany

Source: Fleet Events

A full Sparkassen-Arena, Jena

The W3+ Fair Jena opened its doors for the first time with welcoming speeches from Bodo Ramelow, Minister President of Thuringia, and the Mayor of Jena. Jena's first industry trade fair brought together players from the cutting-edge technologies of photonics, optics, electronics and mechanics in the Sparkassen-Arena. Over 160 exhibitors, partner associations and speakers met some 2,027 trade visitors. "Providing a stage for photonics and neighbouring key technologies has paid off: we will be bringing this enriching live exchange across professional and regional boundaries to Jena every year in future," said Nora Kirsten, managing director of the fair's gold partner OptoNet.

A good third of the exhibition space was occupied by companies from Thuringia. However, exhibitors from other federal states and ten other countries, including the UK, France and the USA, also took the opportunity to present their products to the region. According to the exhibitor survey, 84 % of the companies are already making firm plans to attend the next event in September 2024. It was not just the 23 companies at the joint Thuringian stand that were very busy: "So many good discussions with new and old contacts in a short space of time at the cradle of industrial optics – a format like this was long overdue in Jena," confirmed Dr Jörg Wagner, managing director of LEJ Leistungselektronik Jena and new chairman of the board of OptoNet.

The visitors also gave the event top marks. Most of them came from the region, but even guests from abroad, for example from the Netherlands, Lithuania and Switzerland, used the first event to make contact with companies in Thuringia.

The accompanying en.tech.talks conference, which took place at the same time, also got off to a very good start in Jena. High-caliber speakers from Jenoptik, Zeiss, ASML, the Fraunhofer Society and many more gave talks over two days in front of a packed audience. The interest was high. In addition to the EPIC TechWatch, the Federal Agency for Leap Innovations 'Sprind' sent four start-ups with new ideas to pitch on stage. Silicon Saxony also brought a far-sighted perspective to the podium: closer technological cooperation for central Germany in terms of skilled labor, projects and financing.

The Ernst Abbe University of Applied Sciences presented eight of its current university research projects in the Campus Area. Offers and support for foreign co-operation projects were provided by the Europe Enterprise Network EEN, among others.

Overall, the W3+ Fair was supported by many professional associations and numerous partners from the region, including the Thuringian Cluster Management LEG Thüringen, the Central German Metropolitan Region, the East Thuringia Chamber of Industry and Commerce in Gera, the Tridelta Campus Hermsdorf, the Center for Mechanical Engineering ThZM, Enterprise Europe Network EEN and the medical technology network medways. The latter organized a LifeScience Day specifically for the W3+ Fair.

"The new W3+ Fair Jena is based on the strong photonics sector, the leading photonics location of Jena/Thuringia, our highly motivated partners and the established trade fair concept. This combination enabled us to create real added value for all participants. The W3+ Fair is the perfect marketplace for the entire value chain of enabling technologies – this is where partnerships and ideas for future innovations are born," says Jörg Brück, project director of the W3+ Fair.

The next W3+ Fair Jena will take place on 25 – 26 September 2024. In spring, on 13 – 14 March 2024, the trade fair will celebrate its tenth anniversary at its home venue in Wetzlar.

https://w3-fair.com

Focused on laser developments and their suitability for industrial applications

Review: Laser Symposium & ISAM, 29 November – 1 December 2023, Dresden, Germany / online

Source: Fh. IWS, O. Killig

Impression of Laser Symposium and ISAM 2023

For the twelfth time in a row, Laser Symposium 2023 brought together the world's leading laser experts, end users and newcomers from both industry and academia. With a focus on the latest laser developments and their suitability for industrial applications, it offered an ideal platform for scientific and technical exchange on various aspects of laser materials processing.

The 5th International Symposium Additive Manufacturing (ISAM) highlighted the latest achievements and challenges in additive manufacturing. Fascinating engineering solutions paired with exciting economic benefits are strong drivers for R&D efforts and industrial solutions worldwide.

Combined into one joint conference, Laser Symposium and ISAM provided a unique platform for the exchange of ideas and for industrial networking.

www.lasersymposium.de

Preview: Laser World of Photonics China

20 – 22 March 2024, Shanghai, China

Asia's leading photonics exhibition revolves around innovative products as well as their industrial solutions and applications. The event presents the entire spectrum of photonics.

Originated from Laser World of Photonics, the Chinese spin-off was founded in Shanghai in 2006. As the annual event for the laser, optics, and optoelectronics industries in Asia, the trade fair features five theme areas: lasers and laser systems for production engineering, laser and optoelectronics, optics and manufacturing technology for optics, infrared technology and application, optical metrology and quality assurance. Also, it brings into focus the most popular application fields such as automotive engineering, new energy/lithium battery, medical treatment, consumer electronics and semiconductor. By linking the exhibitors' major achievements with customer needs, the exhibition covers the entire supply chain from manufacturing to end users, promotes smooth transactions, market integration and upgrade, and drives the development of innovative technology that is key to the high-quality development of China.

www.world-of-photonics-china.com.cn

Preview: AKL'24

17 – 19 April 2024, Aachen, Germany

Laser manufacturers and users from various industries will meet for the 14th time at the "AKL – International Laser Technology Congress" in the Eurogress in Aachen. Organized by the Fraunhofer Institute for Laser Technology ILT in Aachen for almost thirty years, this conference has established itself as the leading forum for applied laser technology in production in Europe. 82 speakers will present, and participants will discuss the latest findings from applied research and pioneering achievements in the industry – from smart solutions for functional surfaces, AI-supported laser systems to networked digital manufacturing systems for the production line of tomorrow.

The first day, April 17, will once again be dedicated to parallel expert forums with deep dives into the topics of AI-supported photonics, functional surfaces and quantum technology. At the beginning of the Gerd Herziger Session on April 18, 2024, Dr Peter Leibinger (chairman of the supervisory board of Trumpf), Dr Christopher Dorman (VP, Coherent) and Dr Christoph Rüttimann (CTO, Bystronic) will address the question – from the perspective of technology suppliers – of how business models and value creation in laser technology are changing as a result of digitalization and AI. This panel discussion will be led by Prof Constantin Haefner, director of Fraunhofer ILT.

Experts from industry and science will also explain the status and prospects of laser material processing, laser beam source development and medical technology in fifteen expert sessions. All participants will also have the opportunity to make contact with around fifty laser, component, and system manufacturers at the exhibition accompanying the conference and discuss their questions in individual meetings.

All presentations at AKL'24 will be held in English or German with simultaneous translation into the other language. The detailed conference program, registration, including the early bird discount until February 27, 2024, are at:

www.lasercongress.org

Preview: 16th Optatec

14 – 16 May 2024, Frankfurt, Germany

Optatec is known as the leading trade fair in the field of optical manufacturing technologies. It is held regularly once every two years and serves as the meeting place for the optics and image processing sectors.

The trade fair has anchored itself firmly within the industry thanks to its explicit range of products for the development, production and utilization of optical components, optomechanics, optoelectronics, fiber optics, fiber-optic cables, laser components and digital microscopy, as well as processing machines and manufacturing systems for the production of optics. Around 250 exhibitors will present practical solutions in hall 3.1 on 4,500 square meters of exhibition floor space and engage in personal dialogue with their target groups.

Users of optics and other interested parties come to the Optatec from all industry sectors such as robotics and automation technology, laser technology, the automotive industry, aviation and aerospace, medical technology and medical imaging, as well as lighting technology. It is a suitable setting for exhibitors to showcase their new products. Research and science also take advantage of Optatec as a communication platform covering all aspects of photonics.

As a matter of tradition, university representatives organize the 'Training & Research' technology park which promotes a practical transfer of knowledge from research to routine business operations. This information platform is scheduled to take place again in 2024, in order to maintain ties between universities and the optics industry. Not least of all, the technology park is targeted at attracting young professionals and students to the field of photonics.

www.optatec-messe.de

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- Optical Components

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Focus: AKL'24 Laser Congress

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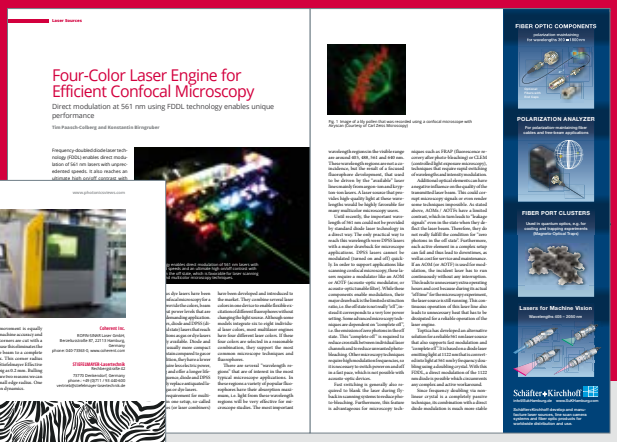

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