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INTERVIEW

"The trick is to find out where those opportunities are"

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Datacom in the era of AI

Introducing higher-speed transceivers at a faster pace than ever before

In the world of transceivers, we are in the early days of a step-change thanks to advances in artificial intelligence. I've just reached my 20-year anniversary with Finisar / II-VI / Coherent. As many of you know, Finisar (now Coherent) was a pioneer in pluggable transceivers so much so that the name Finisar became almost synonymous with transceivers. From telecom networks to enterprise datacenters to web 2.0 hyperscalers, much has changed over the past two decades because of evolutionary and revolutionary changes in the key market drivers.

Today, we're seeing another major market transition, namely the dramatic growth in artificial intelligence (AI) and machine learning (ML). These applications will define the next chapter in the optical transceiver story. By now, many of us have read about or used ChatGPT from OpenAI, Bard from Google, or Bing from Microsoft. In fact, OpenAI's ChatGPT has been called the fastest growing app in history, reaching 100 million users in only two months.

The AI must be trained on an existing dataset, which can contain billions of parameters. This requires significant compute power, which is distributed over tens of thousands of processors. To address these new requirements, datacenters are fundamentally rearchitecting and adding server and networking equipment specifically dedicated to AI and ML. Optical interconnects including transceivers are used at all levels in this network.

Network changes to address AI and ML are driving us and others in the industry to introduce higher-speed transceivers at a faster pace than ever before. 800 G transceivers are shipping in production and we expect the first 1.6 T transceivers will ship in the next few years. In five years, the market opportunity for 800 G and 1.6 T datacom transceivers is expected to be greater than all other types of datacom transceivers combined, largely driven by AI and ML.

There's no doubt that we're entering the era of AI. In fact, we're already in it.

As the industry converges on Glasgow to attend ECOC 2023, we can feel the excitement in how, through optical communication technology, we are helping to bring forth the power of AI and ML. And after twenty years, believe it or not, I'm just as excited as ever to be working in this fast-paced and impactful world of optical communications.

Yours truly

Source: Coherent

Dr Julie Sheridan Eng
Chief Technology Officer
Coherent Corp.

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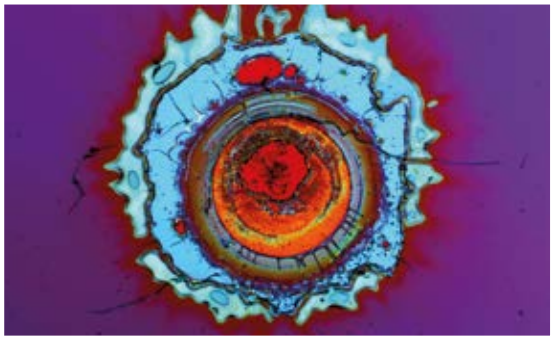

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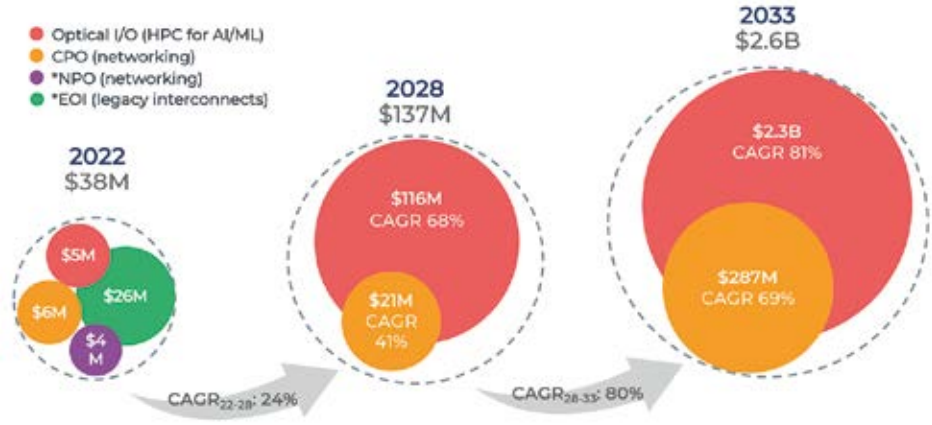
The TECHSPEC 120i Plan APO Infinity Corrected Objectives are specifically designed to reduce overall system size and weight while maintaining optical performance.

These objectives offer easy system integration with C-mount threading making them ideal for a wide range of machine vision applications.

In-package optical I/O, a key enabler for artificial intelligence and machine learning

Leading photonics companies are exploring in-package optical I/O technology to enable communication between computing chips. Through networking applications and especially AI 2 and ML3 systems, CPO4 leads the way, according to an analysis by Yole Intelligence.

AI models have an insatiable demand for compute, storage, and data movement, and the capabilities of traditional architectures will become the main bottleneck to scaling machine learning (ML). As a result, new optical interconnects have emerged for HPC5 and its new disaggregated architecture. Such in-package optical I/O6 technology for xPUs, memory, and storage, can help achieve the necessary bandwidths. The basic idea is to bring optics to very short-reach transmission distances, such as intrarack applications or within a system.



Datacom photonics revenue forecast – EOI and NPO will be replaced by CPO in 2027 (Source: Yole)

In its new report "Co-packaged Optics for Datacenter [sic] 2023", Yole investigates CPO technology. Analysts provide detailed forecasts of the market split by technology architecture and review the industry in detail, including its supply chain. The technological approaches and current challenges are also well described. In addition, this study examines the global challenges and focuses on the power and energy aspects.

According to senior analyst Dr Martin Vallo, "Currently, many challenges stem from using electrical I/Os. Applications such as AI/ML frequently need to move data rapidly from one chip to another or one board to another. Consequently, the computing chips need more communication, either through a larger number of pads or very high speed in a single pad. Additionally, data movement power is the primary driver of power increases in server chips".

In-package optical I/O technology is coupled with packaging innovations such as chiplets and silicon photonics. These solutions provide up to 1000× the bandwidth at a tenth of the power of electrical alternatives. Most of the optical solutions will have a disaggregated, remote laser that provides platform flexibility and replaceability.

www.yolegroup.com

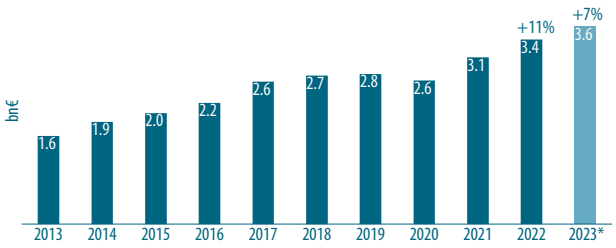
Machine vision again saw double-digit growth

Machine vision sales in Germany grew by 11 % in 2022 compared to the previous year. Overall, sales in the robotics and automation sector grew by 5 % to € 14.3 B in 2022, the VDMA association reports. In addition to machine vision with € 3.4 B in sales in 2022, it consists of the subsectors integrated assembly solutions with € 7.4 B in sales and robotics with € 3.5 B in sales. This means that although machine vision is still the smallest subsector, it had by far the strongest growth.

Strong growth forecast for all subsectors in 2023

For the year 2023, the VDMA Robotics + Automation association predicts growth in machine vision of 7 % to € 3.6 B in sales. Integrated assembly solutions are expected to grow much more strongly, by 17 % to € 8.7 B in sales. Compared to 2022, robotics is expected to grow the most, by 12 % to € 3.9 B.

"The robotics and automation industry is on course for growth," says Frank Konrad, chairman of the VDMA Robotics + Automation association. "In 2023, the previous record result from 2018 of € 15.1 B is likely to be significantly exceeded once again with expected sales of € 16.2 B. The current market situation is good, with full order books. During the pandemic, suppliers built up large order backlogs, which are now being gradually worked off as bottlenecks in the supply chains ease. This means our industry is finally leaving the pandemic behind."



Machine vision sales in Germany grew by 11 percent in 2022 compared to the previous year. (Source: VDMA)

Energy and mobility transition are driving demand

Demand for robotics and automation in manufacturing is being driven by strong transformation trends: the automotive industry is currently developing new manufacturing technology for electric cars, for example. The expansion of renewable energies for climate protection requires the cost-effective and highly automated mass production of green tech products such as fuel cells. According to the German mechanical engineering industry association VDMA, the aim across all industries is to operate more sustainably, to produce competitively in Europe and to compensate for the shortage of skilled workers.

www.vdma.org

SEDI-ATI with new holding and investment fund

The specialist in fiber optic components for harsh and extreme environments SEDI-ATI Fibres Optiques reorganized its shareholding structure and welcomed its new majority shareholder, Yotta Capital Partners, the first French investment fund dedicated to the development and decarbonization of industrial SMEs. The buyout took place on 11 July 2023.

Founded in 1951, the company is recognized as an expert in the design and manufacture of passive components for fiber optic applications, specifically designed for custom applications in harsh and extreme environments. The products have applications in various markets, such as industrial, medical, energy, aerospace, communication, and research. Manufactured in France, SEDI-ATI's products are used, for example, in nuclear reactors, medical diagnosis devices or in the Pharao atomic space clock.

In July 2016, the company was taken over by JF Vinchant Holding Strategy (JFVHS), majority-owned by Jean-François Vinchant, chairman and CEO of SEDI-ATI, with the support of the investment fund IDF Capital.

The recent exit of IDF Capital provided the opportunity to carry out a capital operation with a new investment fund, Yotta Capital Partners. As the first investment fund dedicated to the development and decarbonization of French industrial SMEs, Yotta is backed by BPIfrance, the European Investment Fund and other leading institutional investors, mainly French.

Partners in the transaction around Jean-François Vinchant (front row center; Source: SEDI-ATI)

"My holding company remains a significant shareholder in the new holding company alongside Yotta, and I therefore continue as president and CEO of SEDI-ATI," said Jean-François Vinchant.

www.sedi-ati.com

KDPOF receives investment from the European Commission for chip development

KDPOF is getting access to the € 8.1 B investment fund for their projected packaging plant for optoelectronic devices in Spain. Close to their headquarter in Tres Cantos, Madrid, KDPOF is advancing a high-quality packaging factory for state-of-the-art optoelectronic devices. The company is also developing new optoelectronics packaging technology. It will be applied for the first time to produce the upcoming transceiver IC for high-speed automotive optical communications. Incorporating AI, sensors, and processors in self-driving vehicles requires the company's technology to interconnect all components robustly and inexpensively using fiber optic links within the vehicle.

"The funding supports us in making our plans to manufacture ICs in Europe come true in the near future," states Carlos Pardo, CEO and co-founder of KDPOF. "European fabs only manufacture approximately ten percent of semiconductors worldwide, making us dependent on Asia and the United States. We will pioneer the manufacturing of automotive optoelectronics in Spain in high volume, and reducing this dependency."

The project called "IPCEI ME/CT" was jointly prepared and announced by fourteen member states: Austria, Czechia, Finland, France, Germany, Greece, Ireland, Italy, Malta, the Netherlands, Poland, Romania, Slovakia, and Spain. The member states will provide up to € 8.1 B in public funding, which is expected to unlock an additional € 13.7 B in private investments.There are 56 companies participating in this project. It is also expected that their 68 projects will generate a total of 8,700 direct jobs.

www.kdpof.com

OFS Fitel manufacturing draw towers and facility acquired by Heraeus Comvance

Since the 1970's, Heraeus has helped shape the telecom industry. It has now bought a part of the OFS Fitel Denmark plant in Brøndby near Copenhagen to manufacture standard optical telecommunication fibers based on a European value chain and will provide these fibers to the EMEA market. OFS will also continue to produce and market specialty fiber in Brøndby for the global market, and Furukawa Electric, OFS's parent company, will continue serving the global market with a full portfolio of telecommunication fibers from state-of-the-art draw towers in Japan.

"The OFS focus at its Denmark site remains the production of world-class, unsurpassed attenuation sub-sea fibers and other specialty communications fibers," explains Holly Hulse, president and CEO of OFS. "The divesture of telecommunications equipment and manufacturing space will not adversely impact OFS' production and supply of specialty fibers and is in line with the company's strategy for long-term growth and profitability."

"Heraeus Comvance is one of the largest manufacturers of synthetic quartz glass which will remain our main business focus globally. To cater specifically to the EMEA market, we have now taken the next step along the value chain with the production of bend insensitive and standard optical fibers at our facility in Denmark. They will be made in the European Union from glass to fiber. With this engagement we will better serve our global glass customers," explains Dr Jan Vydra, president of Heraeus Comvance.

www.heraeus.de
www.ofsoptics.com

Hamamatsu expands production of microfocus X-ray sources

To meet increasing demand, Hamamatsu Photonics has completed a new building for the production of microfocus X-ray sources (MFX) and other electron tube products. The recently completed Building No. 11 at Hamamatsu Photonics' Toyooka site will commence manufacture in August. It was officially inaugurated on August 4, 2023.

Source: Hamamatsu

The recently completed Building No. 11 at Hamamatsu Photonics' Toyooka site

Hamamatsu expects sales of these products to increase steadily. In particular, demand for microfocus X-ray sources, which are used with imaging equipment in non-destructive testing of printed circuit boards for data servers and batteries for electric vehicles, is rising rapidly, so the company urgently needs more production capacity, Hamamatsu informs. With this expansion, the company expects to increase sales of its electron tube business to ¥ 100 B (about € 641 M) by the end of the fiscal year 2027.

The new building has an area of just over 24,000 square meters, which includes four floors for production and a canteen. It provides a total of 200 jobs. The construction cost around € 64 M.

https://camera.hamamatsu.com

Jenoptik opened new medical technology site in Berlin

More than one hundred Jenoptik employees will develop and manufacture optical components and systems especially for dentistry (intraoral scanners) and robot-assisted surgery at a new production facility.

Over the past six months, the company has invested around € 20 M in the new site on "Gross-Berliner Damm" in the Berlin district of Treptow-Koepenick. State-of-the-art space will be available, including more than 1,000 square meters of clean room production space and around 600 square meters of logistics space as well as office and recreation rooms. Additional space of the same size will be held in reserve for future growth.

Source: Jasmin Beer, Jenoptik

Jenoptik board member Ralf Kuschnereit, CFO Prisca Havranek-Kosicek and Berlin District Mayor Oliver Igel (l–r) cut the ribbon of the new medical technology location on June 23rd.

"I would like to thank the entire team, which completed the project in such a short time and under conditions that were not easy," said Dr Stefan Traeger, president and CEO of Jenoptik.

www.jenoptik.de

Lynred breaks ground on new 85 million euro industrial site

The global provider of high-quality infrared detectors for the aerospace, defense and commercial markets, Lynred, has been breaking ground on its new € 85 M ($ 93.7 M) industrial site to produce state-of-the-art infrared technology. This is the biggest construction investment that the company has undertaken since it began manufacturing in 1986.

Source:Hélène Bottarel, Groupe-6

Le campus de l'infrarouge

Lynred will double its current cleanroom footprint, totaling 8,200 square meters (88,264 sq.ft.), primarily obtain an optimal clean room cleanliness classification for its new high-performance products (hybrid detectors). It will also increase the production capacity for its more compact industrial products (bolometers) used in multiple fields, including the automotive industry.

This substantial investment will consolidate Lynred's positioning as European market leader in infrared detection.

The new buildings will be located on the current Lynred site in Veurey-Voroize, situated within the Grenoble area.

www.lynred.com

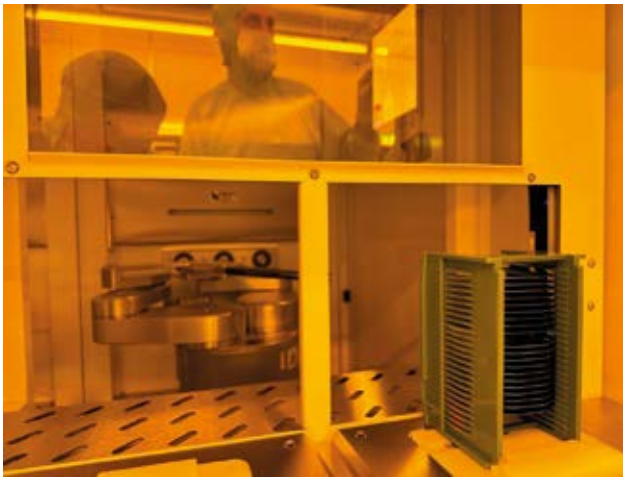
100 million euros for Smart Photonics

The Dutch foundry for PICs has secured an additional round of funding from a group of strategic industrial and financial players.

With this new investment, Smart Photonics will be able to strengthen its position as a manufacturer of next generation chips in a growing, resilient European photonic value chain. The company will use the funds to extend its manufacturing capabilities and accelerate the development of its photonic integrated chip technology platforms and its process design kits (PDKs).

"We are very pleased to be supported by this new group of lenders and are grateful for the continued support of our existing investors," comments Johan Feenstra, chief executive officer of Smart Photonics. "With this round of funding, we receive strong support from the Dutch ecosystem including strategic lenders and financial institutions in our ambition to become the globally leading foundry for photonics integrated chips (PICs)."

The group of new lenders for Smart Photonics is comprised of strategic players from the semiconductor industry – ASML, NXP, and VDL Groep – as well as financial institutions ING, BOP Impact Ventures, and Deep Tech Fund, which is part of Invest-NL and partly funded by the ministry of Economic Affairs and Climate Policy.



In the Dutch company's clean room (Source: Smart Photonics)

Previous investors, including Innovation Industries, BOM, Photondelta and KPN Ventures have joined in this funding round again. The government of the Netherlands will provide sixty million euros public funding as part of the approved National Growth Fund project PhotonDelta as previously announced.

https://smartphotonics.nl

Prima Industrie sells laser biz to Lumibird

The subsidiary of Prima, Convergent Photonics, focused on the development and production of both industrial and medical diodes and laser sources. It has over fifty years of experience in the design and manufacture of semiconductor lasers and laser diode packaging, as well as the design and manufacture of high-power fiber lasers for the medical sector (urology, surgery, etc.). Eighty qualified and experienced people, divided between Italy and the USA, will now join the Lumibird group. The Convergent activities had a turnover of € 15 M in 2022 for a negative EBITDA of € 1.5 M.

The sale of Convergent will allow Prima Industrie to increase its strategic focus on its core business, with the goal of further strengthening its leading positioning in the market of laser cutting and sheet metal processing machinery.

This transaction is in line with the growth strategy launched by Prima Industrie management, aimed at optimizing processes, increasing operational efficiency, as well as accelerating international growth and strengthening technological leadership.

Thanks to this acquisition, Lumibird, one of the European leaders in laser technologies, will strengthen its strategic positioning in lasers and optoelectronics applications, with the goal of expanding into new market segments and increasing its ability to innovate. The transaction is expected to be completed in the second half of 2023, subject to the approval from regulatory authorities in Italy and the United States.

Marc Le Flohic, chairman and CEO of Lumibird, said: "This acquisition strengthens several of our technological pillars and is perfectly in line with our strategy: it allows us to vertically integrate critical semiconductor technologies, to strengthen our sovereignty over laser technologies in Europe, and to diversify into high growth markets."

www.lumibird.com

www.primaadditive.com

More than 200 billion VCSELs for sensing

Coherent has shipped more than 200 billion vertical-cavity surface-emitting semiconductor laser (VCSEL) emitters to date for sensor applications. "In 2013, we began working on two-dimensional VCSEL arrays for 3D sensing in smart phones," said Dr Giovanni Barbarossa, Coherent chief strategy officer and president, materials segment. "We scaled our production capabilities from 3-inch to 6-inch wafers in 2017, just in time to help enable the market launch of the first smartphones with facial biometrics. We believe sensing applications based on semiconductor lasers will continue to expand into new and exciting applications such as in smart watches for health monitoring and in smart glasses for extended reality. VCSELs will also continue to enable a growing market for in-cabin sensing and lidar in automotive."

Coherent continues to innovate in sensing through vertical integration of differentiated technologies. The company recently announced a new VCSEL module technology that enables ultra-compact pattern projectors, flood illuminators, and tightly integrated sensing subsystems.

www.coherent.com

Source: Coherent

No smartphone can be smart without sensing.

Trotec opens up new strategic business area

At the beginning of April, the new 'solutions' business unit was established. It focuses on customer-specific industrial laser solutions and will present some new products, such as for inline marketing, before the end of this year. This will complement Trotec's existing product portfolio and, in the future, customers will be able to laser process large series in their production line in short cycle times.

Competent team "solutions" business unit (Source: Trotec)

Trotec has assembled a team of specialists through internal and external recruitment to meet the technical and professional challenges. In addition, Harald Böhler, who has been managing director for the Markdorf location for several years, will take over the further technical development of the business unit as CTO. Together with the industry specialist Franz Eder, as CSO responsible for sales expansion, both take over the management for 'solutions', and explain: "The bundled competences will help us to optimally support globally positioned industrial producers and to expand this business area."

Strategically located in the four-country corner, the Trotec site in Markdorf lies directly at Lake Constance. For years, the marking lasers of the SpeedMarker product family have been produced there, as well as customized laser solutions for a wide range of industrial applications. This extensive industrial experience is being utilized and the existing customizing specialist team is being integrated into the new business unit.

www.troteclaser.com

Record revenue in 100th anniversary year

German high-tech company Trumpf released preliminary figures for anniversary fiscal year 2022/23: revenue reaches an all-time high of € 5.4 B, up by 27 % on the previous year (€ 4.2 B).

In the domestic market, revenue rose sharply by more than 30 % to some € 770 M (previous year: € 589 M). In the US, Trumpf continued the strong growth of the previous year, posting revenue of some € 900 M (previous year: € 649 M). The strongest Asian market was China with revenue of some € 600 M (previous year: € 575 M).

Furthermore, the company started the new fiscal year with a bulging order book: order intake once again surpassed the five-billion-euro mark at € 5.1 B, but was down by some 9 % on the peak level of the previous year (fiscal year 2021/22: € 5.6 B).

Nicola Leibinger-Kammüller, chief executive officer of Trumpf, remarked: "Despite ongoing difficult conditions, we achieved an outstanding fiscal year in our centennial. Nevertheless, we have been witnessing a decline in orders in recent months due to the global economic slowdown. As such, we are entering the new fiscal year with due caution in spite of a solid order book."

The group's headcount has now risen to around 17,900, including some 8,800 employees in Germany as of 6/30/2023, approximately 5,800 of whom work at the company's headquarters in Ditzingen.

www.trumpf.com

Haag-Streit UK moves to new premises

The new UK HQ is just ten miles away from the previous Harlow location, where the company has been for more than thirty years. It includes an open-plan office which can accommodate the HS-UK team perfectly, as well as an exciting new space to hold Academy courses. The logistics and service team will be located in a separate, well-sized warehouse facility.

The HS-UK premises in Bishop's Stortford, Hertfordshire (Source: HS-UK)

The new premises are close to road and rail links, just off the M11 motorway and a stone's throw away from Stanstead airport. The new premises comprise two buildings that encourage collaborative working, improved workflow and sustainability initiatives.

HS donated a lot of the furniture from the old office building to local Harlow schools and charities, who were very grateful. New furniture was sustainably sourced, and both new facilities will benefit from solar energy and electric car charging spaces.

Dean Johnson, HS-UK managing director, said, "This is a very exciting time for HS-UK as we move into our new home in Bishop's Stortford. The new offices are very well located and have a more modern look and feel. We look forward to welcoming both customers and colleagues for meetings, as well as inviting delegates to attend training in our new dedicated academy space."

Haag-Streit UK designs, manufactures and distributes a complete portfolio of ophthalmic diagnostic and surgical equipment, including slit lamps, biometers, perimeters, OCT devices, lasers, medical simulators, and microscopes. The Haag-Streit group, headquartered in Koeniz near Bern, Switzerland, is an internationally operating medical device company in the field of eye care.

www.haag-streit.com

Qugantic: using qudits instead of qubits

A new project intends to build and test a prototype hybrid integrated PIC based on quantum digits which have more than two states as opposed to qubits with only 0 and 1. These are generated by quantum frequency combs with the potential to execute operations in a reduced number of steps and provide the first scalable PIC quantum computer.

The project, supported by the EU/EIC, has officially launched with a kick-off meeting that took place in April at Aarhus University in Denmark. Members of the project team from three countries discussed the start of the project and plan for the first milestones. The name is an abbreviation for "Quantum-generative adversarial networks with photonic integrated circuits".

Qugantic kick-off meeting in Aarhus (Source: Quix)

Storming and penetrating the market today is generative AI. This is a type of artificial intelligence system capable of generating text, images, or other media in response to prompts. Generative AI models learn the patterns and structure of their input training data, and then generate new data that has similar characteristics. In that are generative adversarial networks (GANs), which are classes of machine learning frameworks and prominent frameworks in approaching generative AI.

The project comprises: QuiX Quantum (Netherlands) and Kvantify (Denmark) as SMEs, and Aarhus University (Denmark), Gottfried Wilhelm Leibniz University Hannover (Germany), Technical University Eindhoven (Netherlands) as academic organizations.

www.quixquantum.com

Qant and IMS Chips produce quantum chips together

The Stuttgart-based start-up and the Institute for Microelectronics Stuttgart (IMS Chips), signed an agreement to jointly manufacture the first quantum chips in small batches in just two years. As a leading quantum technology company, Qant contributes its know-how in quantum computer chip production to the cooperation. In addition, the start-up is contributing machines and process technology in an initial investment worth € 14 M.

IMS Chips is participating with its existing machinery. Quantum chips are considered central building blocks for quantum processors, which will provide a speed advantage in the future, for example in the environment of high-performance computing centers. In addition to clean room production with appropriate equipment, IMS Chips also brings experts with experience in industrial-scale manufacturing to the cooperation. In return, the start-up invests in manufacturing capacity and equipment geared toward quantum technologies. For the IMS, which is a foundation of the state of Baden-Württemberg, the cooperation offers the opportunity to advance research and development activities.

Qant CEO Michael Förtsch and IMS Chips director Joachim Burghartz present a quantum chips wafer (Source: Qant)

In addition to quantum processors, the photonic chips are to be used in a wide variety of industries in the future: the fields of application range from medical technology, sensor technology and telecommunications to cryptography, logistics and the financial sector. In contrast to other quantum computing solutions, the photonic chips are operated at room temperature. Qant relies on a specially developed lithium niobate technology platform for its chips.

https://qant.de
www.ims-chips.de

ALSO OF INTEREST

Your daily quantum of photonics news

WIN NEWS

Kimsoptec renames to Instrument Systems Korea

After being acquired in 2022, the Korean manufacturer of display measurement systems changed its name

MVTec opens its own educational institution

A new MVTec Academy should make it easier to get started with industrial image processing

Resolve Optics has opened a new vibration test center

In the new facility, the in-house lens devices are primarily tested

MKS celebrates 50 years at Laser World of Photonics

As one of the early exhibitors, the company looks back on a long history in the photonics industry

Pieter Blok wins EMVA Award

Young Professional Award 2023 for the work "Advanced deep learning for harvest robotics"

Robot sales in North America up 12 percent

The North American robotics market reaches a total of 41,624 units in 2022

Bayern Kapital sells its stake in Extend3D

Successful exit with the invested business angels and the founders to Atlas Copco

Fraunhofer IPMS founds technology center for semiconductor measurement technology

Institute wants to open a new facility in Dresden together with a partner

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WIN NEWS

ASML and Imec will work together more closely in the future

Imec and ASML intend to intensify their collaboration in the next phase of developing a state-of-the-art high numerical aperture (high NA) extreme ultraviolet (EUV) lithography pilot line at Imec. This is intended to help the industries using semiconductor technology to understand the opportunities that advanced semiconductor technology can bring and have access to a prototyping platform that will support their innovations. The collaboration between Imec, ASML and other partners will enable the exploration of novel semiconductor applications, the potential development of sustainable, leading-edge manufacturing solutions for chip makers and end users, as well as the development of advanced holistic patterning flows in collaboration with the equipment and material ecosystem.

A signed memorandum of understanding includes the installment and service of ASML's full suite of advanced lithography and metrology equipment in the Imec pilot line in Leuven, Belgium.

IMEC and ASML intensify their collaboration (Source: Imec)

www.imec-int.com
www.asml.com

New clean room for microchip production

The Technical University of Denmark DTU is expanding its facilities to meet high demand for microchips from companies and researchers. The expansion will also strengthen the development of quantum computers, which requires the research and development of new chips.


DTU builds new clean room for microchip production. (Source: DTU / ERIK Arkitekter / Tegnestuen Kontekst)

DTU Nanolab conducts research into the micro and nanotechnology on which the production of advanced microchips is based. In addition, DTU Nanolab grants companies and industry access to use the unique facilities in the only large-scale clean room in Denmark. But space is cramped.

The vast majority of all microchips are produced in Asia, including China, South Korea, and Taiwan, while the EU only produces 10 % of all microchips worldwide. But, like China and the United States, the EU now wants to boost its own production of microchips to reduce dependence on producers in the rest of the world.

With a new agreement, the EU will raise € 43 B for microchip production, with € 3.5 B being earmarked for research and development of new chips. The ambition is to increase Europe's market share to twenty percent before the end of the decade.

"Already today, we are experiencing a need for more space. At the same time, we expect demand to increase, as nanofabrication technology is crucial in the development of quantum computers and sensors," says DTU Nanolab director Jörg Hübner.

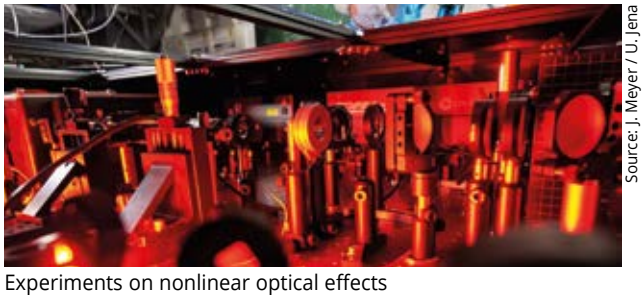
The new cleanroom will be built at DTU Lyngby Campus and comprises an approximately 5,600 m^2 two-floor building with a basement. The DTU-funded building is budgeted at 345 million Danish krones (approx. € 46 M) and expected to be completed in 2026.

www.dtu.dk

€ 11 M funding for nonlinear optics at atomic scales

The collaborative research center on light-matter interactions will be funded by the German Research Foundation for another four years from July 1, 2023. The CRC 1375 NOA – Nonlinear Optics down to Atomic Scales – at the University of Jena has been working on the development of such theories and their practical implementation since 2019 in cooperation with the Fraunhofer Institute for Applied Optics and Precision Engineering IOF and Leibniz IPHT in Jena, but also with the Humboldt University Berlin and the Technical University of Munich. In the CRC, fundamental nonlinear optical processes of light-matter interaction are investigated down to the atomic level.

After these systems have been analyzed and described individually, NOA will investigate systems with mixed dimensionality in the second, eleven-million euro funding phase. These include chemically or electronically modified nanowires or foils, single photon emitters in 2D materials, or atomically thin layered materials. The aim is to tailor the respective nonlinear optical response. New to the CRC is research in the field of quantum optics.


Source: J. Meyer / U. Jena
Experiments on nonlinear optical effects

"With this combined approach, NOA will be able to establish new paradigms for nonlinear optics down to atomic scales, not only in terms of fundamentals but also in terms of applications," says the future NOA spokesperson Prof Stefanie Gräfe.

www.leibniz-ipht.de

Coherent appoints Deputy CTO, head of lasers business

The global player in materials, networking, and laser technology, appointed Dr "YK" Chen as deputy chief technology officer (DCTO) of Coherent, reporting to CTO Dr Julie Sheridan Eng.

Dr Vincent Mattera, chair and CEO, said: "As DCTO, Dr Chen will work closely with Dr Eng to chart the future technical direction of our company, including the creation of new materials for energy generation, transmission, and storage, basic research around next-generation quantum technology. These breakthroughs are required for the sixth generation of wireless networks, and the adoption of digital technologies, machine learning, and artificial intelligence across our operations and in our products and services."

Prior to being named DCTO, Dr Chen was chief scientist in Coherent's new ventures and wide-band-gap electronics technologies group. Before joining Coherent in 2021, he was a program manager at Darpa, and a senior director at Nokia Bell Labs, responsible for high-speed electronics and optoelectronics. He received his PhD from Cornell University in electrical engineering, is a fellow of Bell Labs, IEEE, and Optica, a member of the National Academy of Engineering.

Coherent has also named Dr Christopher Dorman executive vice president, lasers business, responsible for the lasers segment across the markets of precision manufacturing, semiconductor and display capital equipment, life sciences, and scientific instruments, driving operational excellence and customer focus.

Source: Coherent

Dr Young-Kai ("YK") Chen

Source: Coherent

Dr Chris Dorman, MA, OBE

"Dr Dorman's 21-year tenure with Coherent and his recognized expertise in laser technology make him the perfect choice to lead multiple businesses within our lasers segment," said Dr Mattera. "He established the blueprint for our world-class facilities for laser design and manufacturing in Glasgow, Kaiserslautern, and Lübeck." He joined Coherent in 2002 and was most recently SVP and GM, based in Coherent's state-of-the-art facility in Glasgow.

He graduated from Oxford University with an MA (Oxon) in physics and holds a PhD from Imperial College, London. He is currently chair of the UK Photonics Leadership Group, chair of Photonics Scotland, a visiting professor to the University of Strathclyde, and a fellow of the Institute of Physics. He was recognized by Queen Elizabeth II with an OBE for services to photonic and laser technology and exports in the 2019 Birthday Honors list.

www.coherent.com

III-V Epi CTO new professor at AIPT

CTO and technical advisor to III-V Epi Richard Hogg takes on a new role as professor of photonics at Aston Institute of Photonics Technology (AIPT) in Birmingham, in May. The new role is a non-teaching position, allowing him to focus more of his time on photonics research, development, and commercialization.

AIPT is among the world's leading photonics research centers, running national and international, research, industrial and commercialization projects in medical, healthcare, telecoms, and datacoms. The institute has over one hundred industrial partners, including Airbus, IBM, Infinera, Thales, BAE Systems, and Nokia Bell Labs and collaborations with over eighty other photonic centers worldwide.

Professor Hogg, said, "I am delighted to be joining AIPT in a new role that not only progresses my academic career, but also draws on my industrial experience at NTT Basic Research Laboratories, Toshiba Cambridge Research Laboratories, and Agilent Technologies. My CTO role at III-V Epi will continue, unchanged, along with the collaboration III-V Epi has with the James Watt School of Engineering at the University of Glasgow. My role at AIPT will bring the company's activities to a new and wider audience."

Source: III-V Epi

Prof Richard Hogg

www.iii-vepi.com

Markus Clement is new CEO of EMAG

Dr Heinz-Jürgen Prokop handed over the CEO position to Markus Clement in April 2023. The previous CEO of EMAG China and an employee for 24 years now heads the group. "My mandate was to lead EMAG until a long-term and forward-looking appointment is found for this responsible position. With Clement, EMAG is now fortunate to have a CEO who knows the company and its business very well, who has proven with his success in China that he can lead EMAG and whom the employees trust," said Dr Prokop.

Markus Clement can look back on a successful career in the EMAG group and has held many positions of responsibility in the group. He started his career in the service division, where he worked for over six years. This was followed by positions in production management, engineering and customizing including twelve years of experience at EMAG China, where he most recently served as CEO.

Source: EMAG

Markus Clement

With a history of 150 years, the EMAG group is one of the few suppliers of manufacturing systems that covers the whole process chain, from soft to hard machining through a wide range of technologies – turning, drilling, milling, gear cutting, grinding, laser welding, ECM deburring, PECM machining, induction hardening and automation.

www.emag.com

Trumpf Photonic Components with new Managing Director


Source: Trumpf

Dr Thomas Dobbertin

Dr Thomas Dobbertin succeeds Dr Berthold Schmidt as head of the Trumpf subsidiary in Ulm, who becomes chief technology officer and member of the managing board of the Trumpf group.

The 48-year-old Dobbertin took over the role as of July 17, 2023. Previously, the electrical engineer served as general manager for the optical sensor technology business units at semiconductor manufacturer AMS in Singapore and was responsible for the laser components business at Osram Opto Semiconductor in Germany. Most recently, he worked for Nanofilm Technology International, a Singapore-based provider of nanotechnology solutions.

In his new role, Dobbertin is expected to further expand the VCSEL and photonics business and the technological know-how of this Trumpf subsidiary which has been part of the group since 2019. It is a leading global supplier of VCSEL and photodiode solutions for consumer electronics, data communications, automotive, industrial sensors and heating systems. The company employs around 300 people worldwide at its HQ in Ulm and at locations in Aachen, the Netherlands, China, Korea, Taiwan and the USA.

www.trumpf.com

Contract extension ahead of time

The supervisory board of Laytec AG has extended the contracts of the two members of the managing board ahead of schedule: Volker Blank and Dr Kolja Haberland were appointed for an additional five years to continue in their current roles as CEO and CTO as a signal of continuity and stability, essential for the further growth and development of the company.

"We are looking back on two successful years and are ready to take on new challenges. As part of our roadmap, we are intensively working on product diversification by introducing new products," says Haberland.

Laytec develops and manufactures integrated optical in-situ metrology for thin-film deposition and etch processes, in-line metrology for roll-to-roll or conveyer-based production lines, as well as stand-alone wafer mapping systems.

www.laytec.de


Source: Laytec

Volker Blank (l), Kolja Haberland

Change in the Executive Board at Sick – Jan-Helmmut Eberhardt takes over as CFO


Source: Sick

Markus Vatter


Source: Sick

Jan-Helmut Eberhardt

Markus Vatter, chief financial and IT officer, will resign from the executive board after seventeen years at the latest by the turn of the year in order to concentrate on his duties in various supervisory bodies. As his successor, the supervisory board appointed Jan-Helmut Eberhardt to the management board.

Markus Vatter joined the board on July 1, 2006. During his tenure, the graduate industrial engineer strengthened the internationalization strategy, significantly expanded the IT infrastructure and thus accompanied the company's development from a sensor manufacturer to a provider of software-based sensor solutions for industrial automation.

The graduate economist Jan Eberhardt was born in Kassel in 1980 and since 2007 has held various management positions at the medical technology company B. Braun, since 2017 as group vice president corporate accounting and controlling.

With this change, the management board of Sick is composed of Mats Gökstorp (CEO), Jan Eberhardt, Feng Jiao, Ulrike Kahle-Roth, Nicole Kurek, and Niels Syassen.

www.sick.de

Lars Mechold elected chair of CEN/TC 123

The European Committee for Standardization (CEN) standards committee CEN/TC 123 – lasers and photonics has elected the Laser Components CTO Dr Lars Mechold as chairman. In this role, Mechold will play an integral part in shaping the development of European standards for lasers and photonics. In addition to large international corporations, representatives from many research institutes and numerous medium-sized manufacturers are also represented in this expert group. They work closely with the worldwide committee ISO/TC 172/SC 9 – lasers and electro-optical systems.

As technical director for Laser Components since 2012, Dr Mechold has coordinated the production of laser optics, laser modules, and fiber optic assemblies. He has also overseen the activities of the development department at Laser Components Germany. He holds a PhD of physics and also a degree in production management.


Source: Laser Components

Dr Lars Mechold

www.lasercomponents.com

WITec Paper Award 2023 recognizes outstanding publications

The WITec Paper Awards 2023 have been presented to scientists from Poland, France and Italy for their work in cell biology, biomineralization and the development of photonic devices, respectively. The competition recognizes three scientific publications per year that contain results acquired with a WITec microscope.
The Gold Award was presented to a group from Kraków (Poland) for their characterization of the development of adipocytes. There are different protocols for obtaining model adipocytes from stem cells that are used for the investigation of obesity and adipose tissue. The authors used Raman and fluorescence imaging to characterize the maturation of adipocytes, and 2D/3D Raman microscopy. The study reveals the limitations of existing model systems and that the chosen protocols can impact the experimental results. These findings are relevant for metabolic studies and applications of tissue engineering.
A collaboration from France received the Silver Award for a study of the biomineralization process of abalone shells. The authors investigated the spatial distribution of the calcium-containing polymorphs aragonite and calcite in abalone shells with Raman imaging and Fourier-transform infrared spectroscopy (FTIR). The understanding of how biomaterials are produced may inspire the development of new materials for technological applications.
The Paper Award Bronze recognizes the development of shapeshifting planar optical elements by a group from Naples. The authors created planar diffractive optical elements such as lenses and gratings using a photo-responsive polymer that can be shaped into a desired morphology by incident light. The morphology defines the devices' optical properties and was verified by atomic force and scanning electron microscopy.

The WITec Paper Award 2024 is now open for submissions. Articles are eligible if they were published in 2023 (in print or online) in a peer-reviewed journal and contain results obtained with a WITec instrument. Publications should be sent as a PDF to papers@WITec.de before January 31, 2024.

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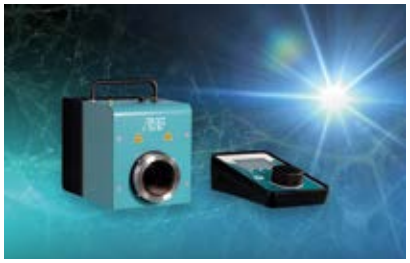
Broadband LED light source

Manufacturer: AHF analysentechnik
Product: New powerful and compact LED light source AF-2100 for fluorescence microscopy, forensics, and multispectral imaging that supports research work with imaging analysis.
Features: The LED source provides two channels that support both simultaneous and separate light output in the ultraviolet and visible spectrum. It works completely silently and vibration-free and allows direct microscope coupling. The AF-2100 can be controlled via TTL, Windows GUI or an external control pod.
Two different LED types for the UV region (365/385 nm) are available to match specific imaging requirements.
The light source is an excellent alternative to classic short arc or metal-halide light sources because a very high light intensity is provided without generating unwanted heat, due to the LED technology used. Advantageous, too, are the long service life, low maintenance costs, very stable intensity output and fast switching times. As it is mercury-free and energy-efficient, it makes lab work safer and more sustainable.



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Website: www.ahf.de

Extended XSWIR hyperspectral camera

Manufacturer: Hinalea Imaging
Distribution: Sphere Optics
Product: Hyperspectral camera model 4455 that covers an extended shortwave infrared spectral range (XSWIR) from 1200 to 2100 nm. It combines high spectral and spatial resolution in a system that is both portable and cost-attractive.
Features: Hinalea Imaging has added a new camera to its innovative product family of hyperspectral imaging systems. This extended short-wave-infrared (XSWIR) camera is designed to cover the 1200 to 2100 nm spectral range. It features a compact, portable and lightweight package and enables the detection and classification of chemicals and other materials that remain unseen with near infrared (NIR) or typical SWIR systems. The model 4455 utilizes a tunable Fabry-Perot filter at its core that can capture a complete high-resolution datacube in seconds across the XSWIR spectral range. It is designed to image 225 spectral bands in hyperspectral mode at a resolution of approximately 15 nm (FWHM). However, the camera can also be operated in multispectral mode. Only a user-defined subset of bands is scanned, optimizing measurement time and enabling near real-time spectral image classification. The ability to dynamically control the sensor based on the application and object to be imaged optimizes the efficiency of both data acquisition and data processing. The growing product lineup of the

manufacturer's hyperspectral imaging solutions provides cost-effective and adaptable high-performance cameras to capture detailed spectral information, whether for scientific research or commercial applications.

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The world's fastest industry standard optical fiber

Fiber contains nineteen cores and can be adopted without massive infrastructure change

An optical fiber about the thickness of a human hair can now carry the equivalent of more than ten million fast home internet connections running at full capacity. A team of Japanese, Australian, Dutch, and Italian researchers has set a new speed record for an industry standard optical fiber, achieving 1.7 Petabits over a sixty-seven kilometers length of fiber. The fiber, which contains nineteen cores that can each carry a signal, meets the global standards for fiber size, ensuring that it can be adopted without massive infrastructure change. And it uses less digital processing, greatly reducing the power required per bit transmitted.

The fiber was developed by the Japanese National Institute of Information and Communications Technology (NICT) and Sumitomo Electric Industries and the work was performed in collaboration with the Eindhoven University of Technology, University of L'Aquila, and Macquarie University.

"Decades of optics research around the world has allowed the industry to push more and more data through single fibers," says Simon Gross from Macquarie University. "They have used different colors, different polarizations, light coherence and many other tricks to manipulate light." Most current fibers have a single core that carries multiple light signals. But this current technology

Source: Macquarie U.

Together with Simon Gross a team of Japanese, Australian, Dutch, and Italian researchers has set a new speed record for an industry standard optical fiber.

is practically limited to only a few Terabits per second due to interference between the signals. "We could increase capacity by using thicker fibers. But thicker fibers would be less flexible, more fragile, less suitable for long-haul cables, and would require massive reengineering of optical fiber infrastructure," says Gross. "We could just add more fibers. But each fiber adds equipment overhead and cost and we would need a lot more fibers. We have created a compact glass chip with a wave guide pattern etched into it by a 3D laser printing technology. It enables the feeding of signals into the 19 individual cores of the fiber simultaneously with uniform low losses. Other approaches are lossy and limited in the number of cores," says Gross. "It has been exciting to work with the Japanese leaders in optical fiber technology. I hope we will see this technology in subsea cables within five to ten years." (Source: Macquarie U.)

Reference: *G. Rademacher* et al.: Randomly Coupled 19-Core Multi-Core Fiber with Standard Cladding Diameter, Optical Fiber Communication Conference (OFC 2023), San Diego, post-deadline paper

www.mq.edu.au

To overcome photonic packaging challenges

3D-printed facet-attached microlenses (FaML) offer new opportunities

Photonic integrated circuits (PICs) are on the verge of significant disruption through the unlocking of novel applications. This success largely relies on advanced wafer-level miniaturized photonic device fabrication, combining outstanding functionality and robustness with unprecedented performance and scalability. However, while cost-efficient mass production of PICs has become widely available through dedicated foundry services, scalable photonic packaging and system assembly still represent a significant challenge and an obstacle towards accelerated commercial uptake. Specifically, package-level optical chip-to-chip and fiber-to-chip connections often rely on so-called butt coupling, where device facets are brought close or in direct physical contact. This approach usually requires high-precision active alignment with submicrometer accuracy, thus complicating assembly processes. Moreover, matching the mode fields can be challenging, particularly when connecting waveguides with vastly different refractive-index contrasts.

A team of scientists led by Dr Yilin Xu and Prof Christian Koos from Karlsruhe Institute of Technology (KIT) has now demonstrated that 3D-printed facet-attached microlenses (FaML) can overcome the scalability challenges of PIC-based solutions.

FaML can be printed with high precision to the facets of optical components using multiphoton lithography, thereby offering the possibility to shape the emitted beams by freely designed refractive or reflective surfaces. Specifically, the beams can be collimated to a comparatively large diameter independent of the device-specific mode fields. This approach relaxes axial and lateral alignment tolerances. The team's findings mean that costly active alignment becomes obsolete and can be replaced by passive assembly techniques based on machine vision or simple mechanical stops. Moreover, the FaML concept allows inserting discrete optical ele-

ments, such as optical isolators or polarization beam splitters, into the free-space beam paths between PIC facets.

Building upon their previous work, the researchers showed the scheme's viability and versatility in a series of selected demonstrations of high technical relevance. In the first set of experiments, they coupled fiber arrays to arrays of edge-coupled silicon photonic (SiP) chips, reaching insertion losses of 1.4 dB per interface with a translational lateral 1 dB alignment tolerance of ±6 µm. This is the lowest loss demonstrated for an edge-emitting SiP waveguide interface with micron-scale alignment tolerances. The researchers further demonstrated that their scheme's outstanding alignment tolerance allows contactless pluggable fiber-chip interfaces using conventional injection-molded parts.

In a second set of experiments, they demonstrated free-space transmission over distances in the mm range, using standard machine-vision techniques for alignment. A third set of experiments was dedicated to interfaces between InP lasers and SMF arrays where the researchers demonstrated the coupling of planar devices through non-planar beam paths comprising only tilted optical surfaces, thus offering ultralow back-reflection.

Based on their exemplary demonstrations of the outstanding versatility of the FaML approach, the researchers believe that their concept opens an attractive path towards advanced photonic system assembly that may overcome most of the current challenges. Opening a path towards scalable and flexible photonic packaging concepts that complement wafer-level mass fabrication of the underlying PIC, the FaML concept addresses one of the most pressing challenges of integrated optics today. (Source: LPC-CAS)

Reference: *Yilin Xu* et al.: 3D-printed facet-attached microlenses for advanced photonic system assembly, Light: Advanced Manufacturing **4**, Article number: 3 (2023); DOI: 10.37188/lam.2023.003

Chip-based dispersion compensation for faster fiber internet

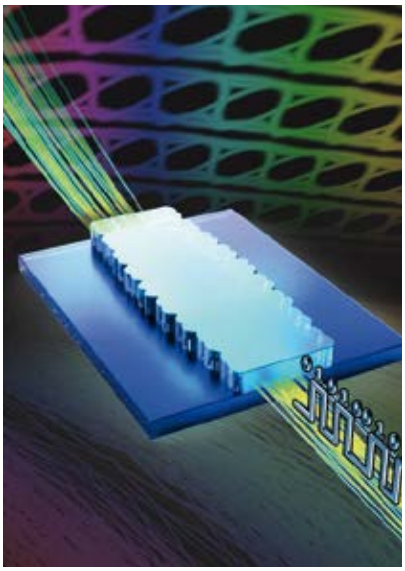
New grating devices significantly reduce data transmission errors

Fiber data transmission is subject to dispersion, or signal degradation from impairments in the optical fiber. Dispersion compensation methods can overcome this problem, with on-chip devices being especially promising as they can be put into the transceivers to increase signal reach. While on-chip dispersive devices exist, none have demonstrated dispersion compensation of high-speed data. This is the gap that researchers from the Photonics Devices and Systems Group of the Singapore University of Technology and Design (SUTD), led by Dawn Tan, aimed to close.

Many integrated dispersive devices are possible, but gratings seemed the most promising due to their advantageous transmission and phase properties. With gratings as their specialty, Tan and her team developed a breakthrough dispersive device. They designed and demonstrated a low loss, CMOS-compatible silicon nitride grating device for the dispersion compensation. The criteria they set out to fulfill in creating this device are three-fold: high dispersion, low data loss, and the small form factor required for on-chip integration. Existing dispersive devices that generate high dispersion show high data loss, while devices that allow low data loss do not generate high dispersion. A device that could do both and be integrated onto a chip would be a significant advancement in data transmission technology. To address this, the researchers designed two grating devices – one with a single grating pitch of 434 nm (single grating device; SGD) and another with two overlaid gratings with dissimilar pitches of 434 and 440 nm (overlaid grating device; OGD).

The transmission spectra of both SGD and OGD are similar. A stopband at both spectra induces forward and backward propagating modes in the gratings. These modes interact and give rise to a slow-light effect, which is the reduction in the velocity of the light pulses. The slow-light effect varies rapidly with wavelength, generating areas of high dispersion. Due to the unique dispersive mechanism of the devices, data loss is minimally affected even with high dispersion. "In this study, both SGD and OGD allowed the dispersion compensation of long fiber reaches up to 20 km with minimal loss. Moreover, both devices achieved improved error correction performance, reducing bit error rates by nine orders of magnitude," described Kenny Ong, PhD candidate at SUTD.

The OGD can also provide a range of dispersion values useful for dynamic dispersion compensation. "Using thermo-optic tuning, one could control the OGD dynamically to compensate for dispersion of various magnitudes, or dispersion



Illlustration of a CMOS-compatible, slow-light-based transmission grating device for the dispersion compensation of high-speed data. (Source: SUTD)

associated with various fiber lengths," Tan added. This can simplify dispersion compensation systems used in different optical communication systems and help reduce temperature or fiber stress effects on data transmission. (Source: SUTD)

Reference: *K. Y. K. Ong* et al.: Slow-Light-Based Dispersion Compensation of High-Speed Data on a Silicon Nitride Chip, Adv. Phot. Res. **4**, 2200290 (2023); DOI: 10.1002/adpr.202200290

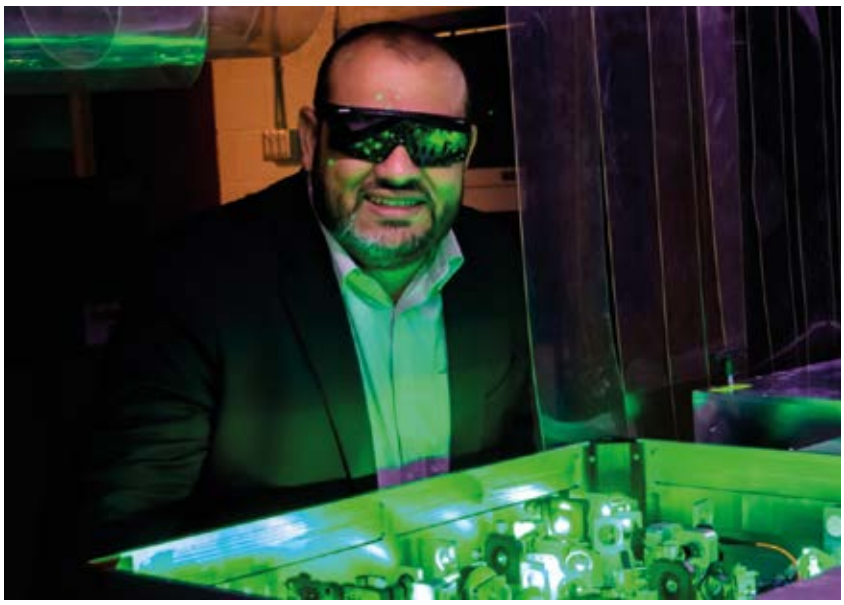
https://photonics.sutd.edu.sg

Optical switching at record speeds

Advancement enables attosecond speeds to reach previously unattainable data transfer speeds

University of Arizona researchers hope to pave the way for faster computers using light-based optical computing, a marked improvement from the semiconductor-based transistors that currently run the world. Researcher Mohammed Hassan said the future of electronics will be based instead on using laser light to control electrical signals, paving the way to the establishment of optical transistors and the development of ultrafast optical electronics.

According to Hassan, the fastest semiconductor transistors can operate at a speed of more than 800 gigahertz. He said one of the primary concerns in developing faster technology is that the heat generated by continuing to add transistors to a microchip would eventually require more energy to cool than can pass through the chip. Now, Hassan and his collaborators discuss using all-optical switching of a light signal on and off to reach data transfer speeds exceeding a petahertz, measured at the attosecond time scale.



Mohammed Hassan led an international team to achieve optical switching of a light signal at attosecond speeds. (Source: M. Hassan, U. Arizona)

While optical switches were already shown to achieve information processing speeds faster than that of semiconductor transistor-based technology, Hassan and his co-authors were able to register the on and off signals from a light source happening at the scale of billionths of a second. This was accomplished by taking advantage of a characteristic of fused silica. Fused silica can instantaneously change its reflectivity, and by using ultrafast lasers, Hassan and his team were able to register changes in a light's signal at the attosecond time scale. The work also demonstrated the possibility of sending data via light at previously impossible speeds.

"This new advancement would also allow the encoding of data on ultrafast laser pulses, which would increase the data transfer speed and could be used in long-distance communications from Earth into deep space," Hassan said. "This promises to increase the limiting speed of data processing and information encoding and open a new realm of information technology." (Source: U. Arizona)

Reference: *D. Hui* et al.: Ultrafast optical switching and data encoding on synthesized light fields, Sci. Adv. **9**, adf1015 (2023); DOI: 10.1126/sciadv.adf1015

https://hassan.lab.arizona.edu

Polynices project launched in Europe

Polymer-based technology platform for hybrid integrated optical components

Polynices is a research and innovation effort to provide a general-purpose photonic integration platform that meets all the cost, performance, scalability and manufacturability requirements for the next generation of photonic modules.

The Polynices project was officially launched with the kick-off meeting held on January 12 and 13, 2023. All eight members of the consortium gathered for a two-day productive meeting at the premises of Toptica in Munich to analyze in detail the Polynices work plan, to specify in detail the role of each partner in the implementation of the project and to define the next actions.

Polynices will develop a fully integrated FMCW THz spectrometer with > 2 THz bandwidth, 8 THz antenna array and beam steering abilities for plastic quality inspection, a 16x16 quantum processor with integrated 780 nm light source and non-linear crystals and a 24×24 quantum processor with integrated squeezed light state source. The Polynices technology provides a holistic approach to photonic integration and packaging and can certainly make advanced photonic modules affordable for SMEs.

Specifically, Polynices will spin-coat Fraunhofer's PolyBoard material on PCBs for the first time to realize a low-cost electro-optical PCB (EOPCB) motherboard with low-loss single mode waveguides and good RF properties, which will host silicon nitride chips, InP components and micro-optical elements for advanced functionalities in properly formed pockets. Polynices takes advantage of LioniX's Si3N4 platform with PZT actuators to realize matrices and novel narrow linewidth external cavity lasers

in 1×1 cm^2 chiplets with ultralow power consumption. The grid array arrangement of the electrode pads of the chiplets and the use of flip-chip integration on vertical alignment stops will allow passive optical alignment and electrical connection to the electrical pads of the EOPCB in a single assembly step. Although the chiplets will accommodate different structures for different functionalities, they will all share the same size, optical and electrical interfaces, defining standard building blocks that lead to tremendous customization and scalability potential with minimal effort and cost. Different functionalities can be installed on the motherboard by selecting the chiplets, or the same chiplet can be installed multiple times to scale the circuit. Most importantly, Polynices provides a unified approach to photonic integration and packaging, as the electronic ICs are co-packaged on the same EOPCB, significantly reducing packaging costs. On the other hand, the good RF properties of the EOPCB allow THz antennas to be integrated directly on the substrate.

The consortium consists of eight partners from four European countries (Greece, the Netherlands, Germany, and Spain). Among those partners, there are three SMEs (Phix, Optagon and Quix Quantum), one industry-oriented research institute (Fraunhofer), two large companies (Lionix, Toptica) and two academic organizations (ICCS and UC3M) with strong exploitation interests and channels.

The partners have been brought together due to their expertise and expected contributions to individual technical aspects of the Polynices project. Some of them are irreplaceable in the sense that their expertise and technical infrastructure are unique in Europe, and thus necessary to achieve Polynices' objectives.

https://horizon-de-polynices.eu

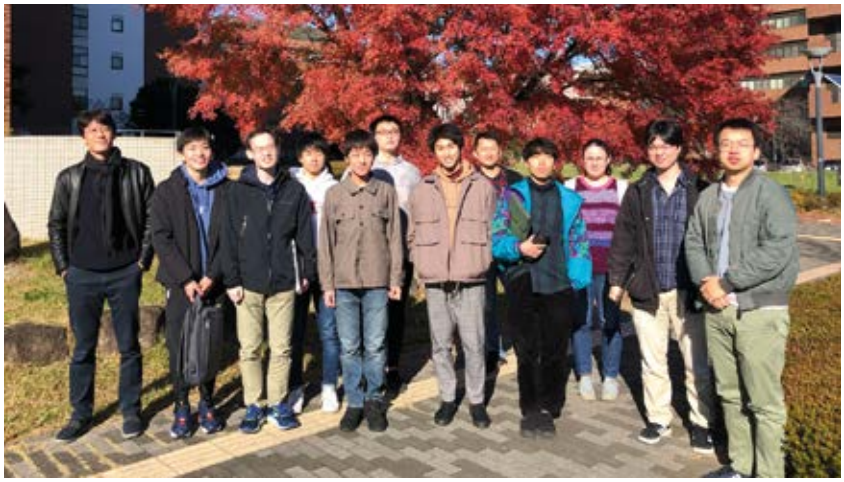
A tunable laser based on liquid droplets

New devices can be inkjet-printed, and have a color that changes based on the shape

Scientists from the Tsukuba Research Center for Energy Materials Science at the University of Tsukuba demonstrated a simple method to produce ionic liquid microdroplets that work as flexible, long-lasting, and pneumatically tunable lasers. Unlike existing droplet lasers that cannot operate under atmosphere, this new development may enable lasers that can be used in everyday settings.

Lotus plants have a remarkable self-cleaning property. Instead of flattening on the surface of a lotus leaf, water droplets will form near-perfect spheres and roll off, taking dust with them. This lotus effect is caused by microscopic bumps in the leaf. Now, the team of researchers have taken advantage of an artificial lotus effect to create liquid droplets that can act like lasers, while remaining stable for up to a month. Currently available droplet lasers cannot be used under ambient conditions, since they will simply evaporate unless enclosed inside a container. In this new research, an ionic liquid – 1-ethyl-3-methylimidazolium tetrafluoroborate ($EMIBF_4$) – was mixed with a dye that allows it to become a laser.

This liquid was chosen because it evaporates very slowly and has a relatively large surface tension. Then, a quartz substrate is coated with tiny fluorinated silica nanoparticles to make the surface repel liquids. When the EMIBF4 is deposited on it from a pipette, the tiny droplets remain almost completely spherical. The researchers showed that the droplet could remain stable for thirty days at least. "The desired morphological and optical properties of the droplet were predicted by mathematical calculations to remain even when exposed to gas convection," says Hiroshi Yamagishi.



The scientists from the Research Center for Energy Materials Science at the University of Tsukuba who developed a new kind of tunable laser. (Source: U Tsukuba)

The shape and stability against evaporation allow the droplet to maintain an optical resonance when excited with a laser pumping source. Blowing nitrogen gas can shift the laser peaks in the range of 645 to 662 nanometers by slightly deforming the droplet shapes. "This is, to our knowledge, the first liquid laser oscillator that is reversibly tunable by the gas convections," says Yamagishi. The laser droplet can also be used as a very sensitive humidity sensor or airflow detector. The researchers then employed a commercial inkjet printing apparatus equipped with a printer head that could work with a viscous liquid. The printed arrays of laser droplets worked without the need for further treatment.

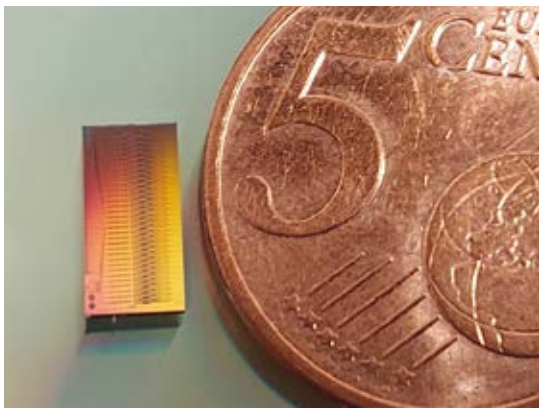
The findings of this research indicate that the production is highly scalable and easy to perform, so that it can be readily applied to manufacture inexpensive sensor or optical communication devices. This research may lead to new airflow detectors or less expensive fiber-optics communications. (Source: Tsukuba U.)

Reference: *H. Yamagishi* et al.: Pneumatically Tunable Droplet Microlaser, Laser & Phot. Rev. **17**, 2200874 (2023); DOI: 10.1002/lpor.202200874

www.ims.tsukuba.ac.jp/~yamamoto_lab

Bringing 'single-chip lidar' into reality

Scantinel Photonics launches groundbreaking 2nd generation FMCW lidar silicon chip



2nd generation FMCW lidar silicon chip compared to a 5 cent coin (Source: Scantinel Photonics)

Achieving a chip-scale massively parallelized photonic integrated circuit (PIC) propels Scantinel Photonics closer to its ultimate goal of developing a 'single-chip lidar' solution. The photonic chip offers an exceptional combination of high pixel rate and high signal-to-noise ratio, enabling the capture of outstanding high-quality real-life data. This advancement is made possible by the chip's unparalleled level of integration, setting it apart in the world of lidar technology and paving the way for the realization of autonomous driving.

"Automotive solid-state scanning lidar requires the co-integration of detectors, laser and ultralow-loss solid-state scanner on the same CMOS-foundry compatible photonic platform. Scantinel Photonics has shown an integrated, massively parallelized detector and scanning chip sharing the same photonic platform as our integrated laser," said Vladimir Davydenko, co-founder of the company.

"The new PIC architecture also enables full in-system calibration leading to significant cost reduction in a volume production environment as it reduces machine investments, fab area and production times," said Andy Zott, managing director and co-founder of Scantinel.

"This high integration into a single chip lidar gives a significant advantage in cost and size over any existing solutions," adds Dr Michael Richter, managing director of Scantinel Photonics.

The launch of Scantinel Photonics' second-generation PIC represents a significant leap forward in its pursuit of a cost-effective and compact lidar solution for autonomous driving applications.

www.scantinel.com

Fabrication of nanophotonic crystals with ultrafast lasers

Nanoscale multibeam lithography to fabricate three-dimensional photonic crystal structures

The light control performance of photonic crystals is closely related to their lattice constant, which typically requires the lattice constant to be in the same order of magnitude as the working wavelength. In crystal materials, the photonic crystal structure is formed by the periodic arrangement of units with different dielectric constants than the crystal itself in space, and its lattice constant depends on the size of the unit and the gap between adjacent units. Therefore, to achieve light control in the near-infrared and visible light range, it is necessary to precisely control the photonic crystal unit structure and gap at the nanometer scale.

A femtosecond laser can directly fabricate three-dimensional micro-nano structures inside transparent materials, which is one of the best ways to construct photonic crystal structures in crystal materials. However, the existing femtosecond laser processing technology for photonic crystals usually adopts a single-beam point-by-point scanning strategy, which is limited in the preparation of nanoscale unit structures due to the overlapping of processing trajectories and motion control accuracy. Microlens array processing technology and laser interference processing technology provide solutions to the above problems to a certain extent. However, the former is not flexible enough, and different microlens arrays need to be designed and fabricated for different target structures. Although the latter has high flexibility, it can usually only be used to process flat two-dimensional structures, lacking three-dimensional customization ability. Therefore, new femtosecond laser processing technology is urgently needed of the preparation of nano-scale three-dimensional spatial photonic crystal structures inside crystals.

A team of scientists, led by Prof Lan Jiang from the Beijing Institute of Technology developed a method for fabricating photonic crystal structures based on nanoscale femtosecond laser multibeam lithography by tightly focusing a multibeam light field with controllable three-dimensional spatial distribution inside a crystal and combining it with chemical etching. On one hand, the size and gap of the fabricated structural units can be controlled at the subwavelength level by designing the optical phase and tight focusing method. On the other hand, the use of a multibeam light field allows for optical control instead of electrical control, effectively avoiding problems such as laser spot overlapping and precision of component movement that exist in single-beam laser processing.

The one-to-one correspondence between spatial phase and the distribution of the light field provides feasibility for this method. The researchers found that the binary phase period and laser flux jointly affect the size and gap of the processed structure, and realized the preparation of subwavelength scale photonic crystal structure units. Based on the above result, by adjusting the grayscale of the binary phase and the superposition method of the final phase, the multibeam light field with controllable laser flux distribution and three-dimensional spatial structure can be customized, and the corresponding complex structure photonic crystal can be processed. (Source: LPC-CAS)

Reference: *Li, J., Yan, J., Jiang, L.* et al.: Nanoscale multi-beam lithography of photonic crystals with ultrafast laser. Light Sci Appl **12**, 164 (2023); DOI: 10.1038/s41377-023-01178-3

Delivering new computing paradigm using photonics

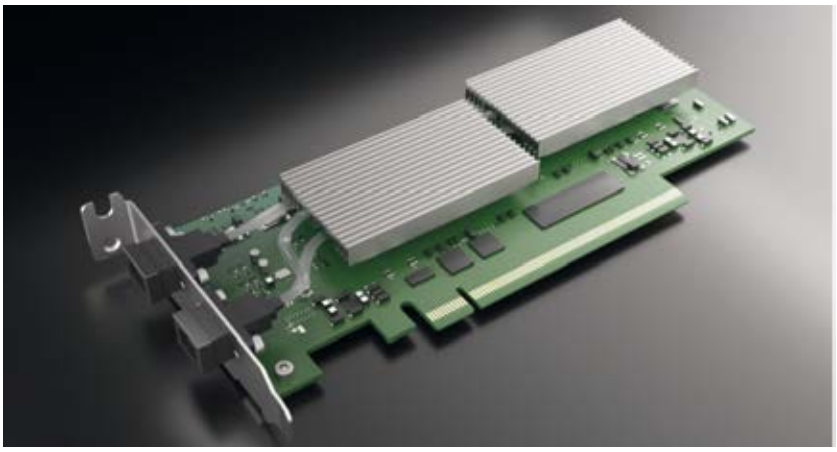
Optical interconnect for composable data center architectures, unlocking infrastructure scalability

Lightelligence, a provider of photonic computing and connectivity systems, has launched Photowave, the first optical communications hardware designed for PCIe and Compute Express Link (CXL) connectivity, which offers next-generation workload efficiency.

Photowave, an optical networking (oNET) transceiver leveraging the significant latency and energy efficiency of photonics technology, empowers data center managers to scale resources within or across server racks. The first public demonstration of Photowave was at the Flash Memory Summit early August in Santa Clara, California.

With the unveiling of Photowave, Lightelligence delivers on its promise of a new computing paradigm using photonics. The product release follows Lightelligence's introduction of Hummingbird, an optical network-on-chip (oNOC) processor for domain-specific artificial intelligence (AI) workloads in June, and PACE, the world's first integrated photonic computing system for optical multiply accumulate (oMAC) in late 2021. "We are more than excited to unveil the next piece of our product portfolio," comments Yichen Shen, CEO of Lightelligence. "Photowave will soon set the standard for workload efficiency. It makes it possible to build scalable computing and accelerator pods with just the right amount of resources."

Photowave provides a solution by interconnecting remote devices together using CXL over lower-latency fiber optic cable, extending reach to enable



Photowave optical CXL hardware (Source: Lightelligence)

As compute and memory stranding becomes an increasingly costly issue for data center workloads, the industry-backed CXL standard enables the disaggregation of compute, accelerator, and memory resources to reduce stranding of resources while improving infrastructure efficiency. The current Ethernet-based infrastructure carries too much latency overhead to enable this disaggregation.

memory pooling at pod scales and beyond. This facilitates scalable CXL fabrics in the composable data center.

The Photowave product line includes various form factors, including a standard PCIe card, OCP 3.0 SFF card, and an active optical cable to achieve successful deployment of CXL-based infrastructure enhancements.

www.lightelligence.ai

Insert ID cards into hair-thin optical fibers

Spatial distribution, reflectivity, and reflection wavelength of Bragg gratings can encode information

Fiber sensing scientists from Shenzhen University have developed an encrypted fiber optic tag that can be used for all-optical labeling and recognition of optical transmission channels such as access networks. The team led by researchers based at the Guangdong and Hong Kong Joint Research Center for Optical Fiber Sensors proposed an all-optical labeling method with encryption property, which uses the feature information and spatial distribution of fiber Bragg grating arrays to flexibly store different coding sequences.

Unlike traditional optical link labeling methods, the all-fiber tag proposed by the team fully utilizes the characteristics of the optical link to achieve all-optical reading, recognition, and restoration of link information. The findings could have a significant impact on the maintenance of optical distribution networks.

The team prepared a fiber Bragg grating array using femtosecond laser multipulse exposure, which can control the characteristics of different grating fragments such as reflectivity, and also allows rapid mass production of tags. It cleverly uses the reflected signal of the grating to increase the number of switch states that the fiber optic tag can represent, thereby improving the storage capacity of the fiber tag. There are many ways of reading and recovering information from fiber optic tags because of the distribution and reflection characteristics of the grating. The adequate security of the tags would be proven by authorized security personnel obtaining the correct optical link information.

One of the lead researchers, Prof Yiping Wang said, "This work fully demonstrates the flexibility of the femtosecond laser direct writing technology, by adjusting the number of femtosecond laser pulse exposures to achieve regulation of the reflection characteristics of each encoded grating fragment, ultimately giving the proposed fiber tag greater capacity and application potential. It is a fascinating and practical way of maintaining existing optical networks." (Source: IJEM)

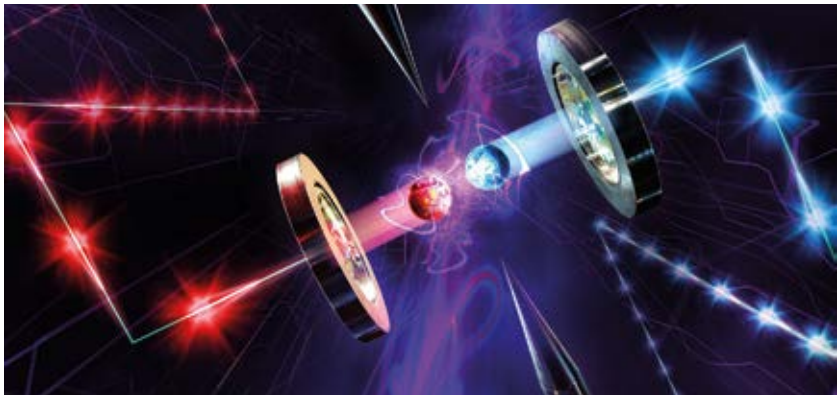
Reference: *Zhihao Cai* et al.: Encrypted optical fiber tag based on encoded fiber Bragg grating array, Int. J. Extrem. Manuf. **5**, 035502, 2023; DOI 10.1088/2631-7990/acd825

Boost for the quantum internet

First long-distance quantum repeater node for telecommunication networks

Quantum networks connect quantum processors or quantum sensors with each other. This allows tap-proof communication and high-performance distributed sensor networks. Between network nodes, quantum information is exchanged by photons that travel through optical waveguides. Over long distances, however, the likelihood of photons being lost increases dramatically. As quantum information cannot simply be copied and amplified, Hans Briegel, Wolfgang Dür, Ignacio Cirac and Peter Zoller, then all at the University of Innsbruck, provided the blueprints for a quantum repeater 25 years ago. These feature light-matter entanglement sources and memories to create entanglement in independent network links that are connected between them by entanglement swap to finally distribute entanglement over long distances.

Quantum physicists led by Ben Lanyon from the University of Innsbruck have now succeeded in building the core parts of a quantum repeater – a fully functioning network node made with two single-matter systems enabling entanglement creation with a photon at the standard frequency of the telecommunications network and entanglement swapping operations. The repeater node consists of two calcium ions captured in an ion trap within an optical resonator as well as single photon conversion to the telecom wavelength.



In order to transmit quantum information over long distances, quantum repeaters are needed to distribute entanglement over long distances. (Source: H. Ritsch, U. Innsbruck)

The scientists thus demonstrated the transfer of quantum information over a fifty kilometer optical fiber, with the quantum repeater placed exactly halfway between starting and end point. The researchers were also able to calculate which improvements of this design would be necessary to make transmission over 800 kilometers possible, which would enable a connection between Innsbruck and Vienna. (Source: U Innsbruck)

Reference: *V. Krutyanskiy* et al.: Telecom-Wavelength Quantum Repeater Node Based on a Trapped-Ion Processor, Phys. Rev. Lett. **130**, 213601 (2023); DOI: 10.1103/PhysRevLett.130.213601

www.quantumoptics.at

New high-heat resin for fiber optics and more

Chemical company Sabic has expanded its product portfolio

The new glass fiber reinforced grades of the ULTEM resin family deliver high flow, custom colorability and high strength, and are well suited for thin-wall components like fiber optics and electrical connectors.

Low-viscosity ULTEM 2120, 2220 and 2320 resins exhibit flow characteristics that make it possible to create miniaturized components with complex geometries. For injection molders, the flow properties of these materials offer the flexibility to lower injection pressures or mold thinner walls at the same pressure. The resins maintain the existing color range of existing resins and can be custom-colored for connector identification and product branding.

The glass fiber-reinforced grades deliver high flow, custom colorability and high strength (Source: Sabic)

The resins are available as ISCC Plus certified renewable versions. In addition, they do not contain per and polyfluorinated substances (PFAS) intentionally added during the manufacturing process and are not expected to contain unintentional PFAS impurities.

Even with glass fiber loadings of ten, twenty and thirty percent, respectively, ULTEM 2120, 2220 and 2320 resins exhibit low viscosity, enabling compact designs with thin walls that expand available space within or surrounding the part. These materials demonstrate higher spiral flow properties of up to thirty-six percent.

In addition, high flow can reduce processing time and production cost. By delivering potential reductions in injection pressure of up to thirty-five percent, the resins can help customers overcome molding equipment limitations. Improved flow can also permit processing temperature reductions that may cut energy costs and shorten cooling times up to ten percent for faster throughput. Finally, high flow helps to mitigate issues such as premature solidification of the resin (freeze off) and visual defects.

The ULTEM 2X20 resins can be custom colored to provide critical identification of the type and speed of fiber optic and electrical connectors, or to enhance the appearance and brand identity of components.

www.sabic.com

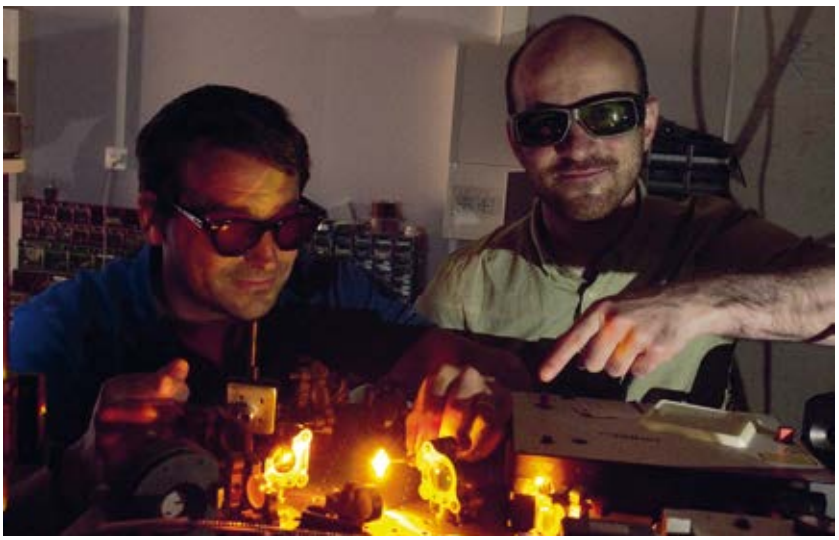
Complex is the scattering of light

More efficient designs of metasurfaces for future optical devices and metaoptical systems

Researchers at the Université Côte d'Azur in collaboration with the Ecole Polytechnique Fédérale de Lausanne and the Zuse Institute Berlin have unveiled a surprisingly intriguing and captivating effect describing light scattering with resonant nanoparticles. By studying the optical response of nanoparticles excited with light oscillating at complex frequencies, i.e. looking at the reflected or transmitted light across an assembly of nanoparticles excited by a time-varying incident light beam, they demonstrated that the positions of spectral singularities – also dubbed poles and zeros – play a major role in the response of the system. More precisely, they realized that a universal 0 to 2π-phase response, which is needed for the design of photonic components, can be imparted on the output channel whenever a zero and a pole forming a pair of complex singularities are placed in the complex frequency plane on either side of the real axis.

The discontinuity line that connects the two singularities (branch cut in complex analysis) provides a full phase modulation when it crosses the real frequency axis. This understanding explains the physics behind most of the modulation effects observed in resonant optical systems, including the so-called Huygens metasurfaces, and it could offer new design rules for the next generation of optical components for traditional 2D and 3D lidar imaging, wavefront engineering, displays and even future quantum optical components.

"Every single component in photonics is conceived to manipulate or to redirect the light coming from the environment. If you want, we could simply say that photonic components are intrinsically open systems, coupled to their surrounding environment via radiative channels. The presence of lossy channels is a total game changer as these systems have to be described using a non-Hermitian theoretical framework," explains Patrice Genevet, a group leader at CNRS-CRHEA in Valbonne, Côte d'Azur, France. Because of the presence of radiative or absorption losses, interesting effects can occur, including complex eigenvalues topology, eigenvector degeneracy and branch point singularities. Complex zero singularities describing the lack of reflection of transmission appear.



Dr Patrice Genevet (left) and Rémi Colom in the laboratory. (Source: CNRS)

The work brings the existence of basic concepts associated with topological photonics to the attention of the nanophotonics and meta-optics communities. It connects peculiar light scattering phenomena with the presence and the position of complex singularities.

The unidirectional forward and backward scattering mechanisms, previously connected to the so-called Kerker conditions, appear to have their origin deeply rooted in the topological and non-Hermitian physics characterized by the appearance of a spontaneous symmetry breaking condition. This strange behavior occurs upon changes in the nanostructure geometry and after encountering an exceptional point, shown by the superposition of two zero singularities. Spontaneous symmetry-breaking is characterized by the modification of the zero positions, bringing non-zero conjugated imaginary parts, i.e. zeros are symmetrically ejected from the real frequency axis. As a result, the system opens a high transmission window of interest to the design of efficient forward scatter: the perfect Huygens source.

While metasurfaces have already been shown to manipulate the properties of light, such as its polarization, phase, and amplitude, enhancing their efficiency and functionality would open new industrial opportunities. For instance in the field of optics and photonics, improved metasurface performance can revolutionize the design of compact and lightweight optical devices, leading to advancements in imaging systems, augmented reality displays, and high-speed optical communications. Furthermore, in the energy sector, efficient metasurfaces can enhance solar energy harvesting and improve the efficiency of solar cells, thereby promoting renewable energy adoption. Additionally, metasurfaces can enable the development of advanced sensing technologies, such as ultrasensitive detectors for environmental monitoring and healthcare applications.

Dr Genevet and his co-workers have revealed that the relative positions of complex singularities are the keys to improve the efficiency of metasurfaces and photonic systems in general that are operating in reflection, in transmission or that can convert polarization. This work could enable an entirely new class of unidirectional or asymmetrical photonic device capable of addressing asymmetrically the response of light to different channels. The concepts discussed in this paper extend beyond the nanophotonics community and could have impact in various fields of research including photonic integrated circuits, quantum optics and electronics. (Source: P. Genevet)

Reference: *Rémi Colom, Elena Mikheeva, Karim Achouri, Jesus Zuniga-Perez, Nicolas Bonod, Olivier J. F. Martin, Sven Burger, Patrice Genevet:* Crossing of the Branch Cut: The Topological Origin of a Universal 2π-Phase Retardation in Non-Hermitian Metasurfaces, Laser Phot. Rev. **17**(6), June 2023; DOI: 10.1002/lpor.202200976

https://2dphotonics.weebly.com

Photonic filter separates signals from noise

Multifunctional filter could support future 6G wireless communication

Illustration of how the integrated microwave photonic filter helps to separate signals of interest from background noise. (Source: Peking U.)

Researchers have developed a new chip-sized microwave photonic filter to separate communication signals from noise and suppress unwanted interference across the full radio frequency spectrum. The device is expected to help next-generation wireless communication technology to efficiently convey data in an environment that is becoming crowded with signals from devices such as cell phones, self-driving vehicles, internet-connected appliances and smart city infrastructure.

The researchers describe how their new photonic filter overcomes the limitations of traditional electronic devices to achieve multiple functionalities on a chip-sized device with low power consumption. They also demonstrate the filter's ability to operate across a broad radio frequency spectrum extending to over 30 GHz, showing its suitability for envisioned 6G technology.

"As the electro-optic bandwidth of optoelectronic devices continues to increase unstoppably, we believe that the integrated microwave photonics filter will certainly be one of the important solutions for future 6G wireless communications," said Xingjun Wang from Peking University. "Only a well-designed integrated microwave photonics link can achieve low cost, low power consumption and superior filtering performance." To convey more data at a faster rate, 6G networks are expected to use millimeter wave and even terahertz frequency bands. As this will distribute signals over an extremely wide frequency spectrum with increased data rate, there is a high likelihood of interference between different communication channels.

To solve this problem, the researchers created a simplified photonic architecture with four main parts. First, a phase modulator serves as the input of the radio frequency signal, which modulates the electrical signal onto the optical domain. Next, a double-ring acts as a switch to shape the modulation format. An adjustable microring is the core unit for processing the signal. Finally, a photodetector serves as the output of the radio frequency signal and recovers the radio frequency signal from the optical signal. (Source: Optica)

Reference: *Z. Tao* et al.: Highly reconfigurable silicon integrated microwave photonic filter towards next-generation wireless communication, Phot. Res. **11**, 682 (2023); DOI: 10.1364/prj.476466

https://ele.pku.edu.cn/dzxxen/Key_Labs/State_Key_Laboratory_of_Advanced_Optical_Communica.htm

With fiber optics against water wastage

A solution against water leakage, which in Italy accounts for one third of the water in the network

These tubes were used during the fiber optics experiments. (Source: Politec. Milano)

Using fiber optic sensors to monitor water networks against wastage: researchers from the Department of Civil and Environmental Engineering pioneered the use of distributed fiber optic sensing (DFOS) based on stimulated Brillouin scattering (SBS) technology to monitor water pipeline networks over long distances. At the heart of this technology is the common and inexpensive optical fiber used for telecommunications capable of measuring deformations to a hundredth of a millimeter.

The scholars worked on high density polyethylene (HDPE) piping, today the most commonly used material for distribution systems. By wrapping and fixing the fiber optic sensor cable on the outer surface of the pipe, they tested the ability to detect deformations related to pressure anomalies along a pipe, such as those caused by water leaks. The experiment consisted of two phases. "In the first one," the researchers explain, "we assessed the sensitivity of the sensor layout on an HDPE pipe stressed with static pressure. This first stage was successful, so we then concentrated on detecting the pressure anomaly produced by a leak in a piping circuit with flowing water. Overall, the results returned positive feedback on the use of DFOS, confirming the ability to identify and localize even very small water leaks."

In the future, the tested technology will be further developed towards industrial-scale production of natively smart HDPE pipes, where DFOS is integrated into the pipe surface during the extrusion process. Water resource wastage is a global issue, increasingly exacerbated by the impact of climate change on the hydrological chain. In Italy, more than one third of the water fed into the national distribution network is wasted. Widespread monitoring and efficient maintenance of the infrastructure are therefore two strategic and urgent actions. (Source: Politec. Milano)

Reference: *M. Bertulessi* et al.: Experimental Investigations of Distributed Fiber Optic Sensors for Water Pipeline Monitoring, Sensors **23**, 6205 (2023); DOI: 10.3390/s23136205

www.dica.polimi.it

“The trick is to find out where those opportunities are”

Håkan Karlsson, head of Hübner Photonics and CEO of Cobolt talks with EPIC’s Antonio Castelo

Source all images: Hübner Photonics

The head of the Swedish supplier of compact single-frequency cw lasers, pulsed lasers and laser combiners in an interview with EPIC’s technology manager for biomedical and lasers.

What is the background to your appointment as head of Hübner Photonics and CEO at Cobolt?

Håkan Karlsson: In 1995, I started a PhD in laser physics and nonlinear optics at the KTH Royal Institute of Technology in Stockholm, Sweden. Prior to that, and quite by chance, I had finished my master’s degree in physics with a thesis on the topic of laser physics in the Hubert Curien Laboratory at the University of Saint-Etienne (France). On my return to Sweden, I developed an interest in lasers and optics and got involved in the development of a new type of technology for nonlinear optical frequency conversion, specifically the periodic polling of nonlinear optical crystals. I did this for a couple of years and ended up doing a PhD focused on how those optical crystals are fabricated and could be used to realize new types of laser sources.

In 2000, after finishing my PhD, my supervising professor and I decided to set up a company to commercialize this new technology by bringing diode-pumped lasers using periodically poled, nonlinear optical materials onto the market. A lot of spin-offs were being created at that time due to the telecom explosion with a huge amount of venture capital available, so it wasn’t difficult to secure investment.

We named the company Cobolt as our initial aim was to develop small and efficient blue lasers, which was something missing on the laser market at the time. Our primary target markets were laser display applications as well as various bio imaging and analysis applications. In the beginning we were making revenues only from the manufacturing and sales of periodically poled crystals, but after a few years of development, we also started to generate revenues from laser products and we could start focusing on profitability. While still operating the business on a relatively small scale, we could start building the company on our own profits rather than looking for more investment.

▲ A selection of visible wavelengths Cobolt lasers

In 2007, I switched from CTO to become the CEO of Cobolt AB, as I felt that my talents lay more in business strategy, sales and organizational development than in developing the technology. However, by 2015, with six million euros in turnover and around thirty employees, it had become apparent, both to me and our investors, that although we had been a profitable operation for many years, Cobolt needed to become part of something new.

In particular, we had become aware that having investors on the board of directors was a disadvantage for our business development. It made us look like a start-up, which was a clear drawback for us when trying to do business with larger organizations who tend to care about their suppliers' corporate and ownership structure.

Accordingly, we began to look for a new industrial owner, i.e., either to be acquired by a company already involved in the laser industry or a company that was looking to expand into photonics. The disadvantage of going with an existing laser manufacturer was that we would risk being absorbed and losing control of the business, whereas we could stay more independent if we opted for a company with a relatively undeveloped position in the photonics community. We were considering both options when by chance we were approached by one of our customers, Hübner, a German multinational industrial manufacturer who were interested in accelerating their development of a photonics division.

We agreed terms in late 2015 under which Cobolt AB became part of Hübner's photonics division. I stayed on as CEO of Cobolt and became head of Hübner Photonics. Since then, we have continued to develop our range of high-performance lasers and systems, including single-frequency cw lasers, multiline lasers, laser combiners, ultrashort pulsed lasers and tunable single-frequency cw lasers. The division now spans five sites worldwide and our main application areas are bioimaging and analysis instrumentation, advanced industrial metrology equipment, the manufacturing of holographic devices and quantum technology research.

At this point, I would like to congratulate you on receiving EPIC's CEO Award 2023

Karlsson: Thanks, I was very honored to receive the award, but it needs to be said that the award should really be seen as a recognition of the hard work and dedication of the entire Hübner Photonics team, not just me!

What have been your main challenges?

Karlsson: The telecom market crashed in the early 2000s, right after we started. It was a very turbulent time for many start-ups, including us. But luckily we managed to survive as we hadn't taken on a lot of debt. And as we hadn't gone into telecoms we weren't pouring lots of money into what was then considered highly uncertain markets. Most importantly, we had already some income from customers through the sales of periodically poled crystals.

Håkan Karlsson, Head of Hübner Photonics and CEO of Cobolt AB, at the Cobolt site

As regards selling the company, the main challenge I think has been that not everyone at Hübner was convinced that starting a photonics division was a great idea. As a result, I had to spend a lot of time in the first few years informing and explaining to Hübner management and employees why we were there and why it would be good for them.

A continuously challenging set of tasks is to monitor and try to understand what customers are looking for, see what competitors have to offer and figure out how we can position ourselves to be the best choice for customers in particular situations. If you are not the best choice in the world for a customer looking for a particular product, everything taken into account, there should be no real reason for the customer to buy from you. We are committed to serve our customers with the best possible solution they can get and the trick is to find out where those opportunities are.

What are your main lessons learnt from founding and developing a start-up in the photonics industry?

Karlsson: Firstly, it is easy to think that you know how markets will develop and what customers want, but you can never really know for sure how and why you can sell a product until you start interacting with paying customers. There is a large range of features of a product that can make it attractive for a customer, but what you think is going to be the most important ones for the customers and what makes you stand out from your competitors may not align completely with what customers think or need.

Secondly, many companies, including us in the beginning, believe too much in their core technology. We thought we had a core technology that would automatically differentiate us from our competitors, so the products would virtually sell themselves. But what we learnt is that the core technology is just a tiny piece of the total offer to the customer. It is not enough to be good in optics, photonics or lasers and physics to make a good product: what is equally if not more important to the customer is the quality of the engineering, the robustness and user-friendliness of the product, which all sums up in the cost of ownership.

Thirdly, as regards the scarcity of talent in our industry, there are a lot of young MSc students out there who, like me, simply have no idea about lasers and optics, how exciting they are and what fantastic things you can do with them. As an industry, we are missing out on them, and we need to spend more resources promoting photonics to young science students as an exciting area for the future with a lot of interesting career opportunities, both in science and industry.

What advice would you give as regards selling a company?

Karlsson: If you want to make an exit at an early stage and you haven't been in the industry very long, then it is probably best to hire an advisor because they have an established network and a good overview of the industry. However, if you have been in the industry for several years, you will have a pretty good idea of who could be a potential buyer and you can make your own short list and approach the companies yourself, at least initially. If, like us, you are suddenly approached by a company, you will have to decide whether to accept the proposal or start the process to find competitive competing bids.

How do you see the future?

Karlsson: Our aim is to grow the company through a mix of organic investments and appropriate acquisitions. Overall, the future looks good for most photonics companies because there are so many new technologies being developed on a large scale for a variety of end user industries; increased adoption of optical technologies for nondestructive analysis and medical diagnosis are two examples. Quantum is another exciting area as well as the development of technology for augmented reality and smart optical materials. There is also the ongoing deployment of laser-based technology for advanced material processing applications, which continues to drive new market opportunities. Of course, there is going to be a fight over those markets, but we see a lot of opportunities for continued strong growth, not only for us but for the whole industry. And, more importantly, we see that the developments in the photonics industry really help to improve our society, with better and cheaper healthcare, better connectivity and a reduced negative impact on the climate by us humans.

If you started again, what would you do differently?

Karlsson: One thing we would do differently is not look for venture capital funding so soon. Back when we started, the general trend was to try to secure venture capital as soon as possible. But in hindsight, I think we would have benefited from using more soft money development for a couple of years before committing ourselves to investors.

What is your advice for the next generation of entrepreneurs?

Karlsson: Firstly, it is crucial not to forget about the engineering expertise; your product is not just laser science, and the engineering quality is equally important for the customer.

Secondly, engage with customers at a very early stage because the information you receive will help you to direct your research or product development in the right direction.

Thirdly, don't underestimate and the importance of having fun, even when times are tough. If you get absorbed by the difficulties, it is virtually impossible to carry on. We have had our difficult times, but we have a celebratory culture in the company, and we have been good at celebrating, even when business has been rough.

Author

Antonio Castelo-Porta is a physicist specialized in optics and a program manager at the European Photonics Industry Consortium (EPIC). After obtaining a PhD in applied physics with a specialization in the laser processing of materials, he explored the industry as a sales engineer and sales manager for several added value distributors and manufacturers. At EPIC, Antonio is in charge of the development of the laser and medical fields, and all related technology and applications. He has a strong interest in new technology involving photonics, such as ultrafast lasers, new medical devices and spectroscopy solutions.

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Proud about our past

EPIC is looking forward to more 'photonastic years' with its members

All the attendees of the 20th Anniversary Celebration gathered together on the stage at Messe München. (Source: EPIC)

In the past two decades, there has been remarkable growth in photonics, leading to numerous Nobel Prizes awarded for scientific breakthroughs in this field. We proudly celebrated these achievements during our anniversary celebration in Munich this past June. During that special evening, we brought together influential figures from the photonics community, including Peter Leibinger (chairman of the board of Trumpf), Mats Hede (managing director of Photonics Nordics), Stéphane Bussa (CSO at PI), Reinhard Pfeiffer (CEO, Messe Muenchen), and Tom Pearsall (founder of EPIC) who all gave inspirational talks. Hosting the event was Carlos Lee, director general of EPIC, who prepared an exciting magic trick for the occasion. You can see all the pictures and special videos prepared for the occasion here:

https://www.flickr.com/photos/epic-photonics/albums/72177720309353124

As autumn begins, we are brimming with energy and excitement for our jam-packed agenda. In September, we have several important trips planned: first, we head to Poland to explore the relevance of photonics in the defense sector. After that, we are off to Exail facilities in Paris to discuss photonics for space. Towards the end of the month, another team will visit Switzerland to engage with experts at Park Innovaare, focusing on photonics for bio and life science applications. Just one week later, we will be attending the ECOC conference in Glasgow, where we will organize our signature events like the VIP Networking Reception and Techwatch. But that's not all; EPIC is dedicated to serving the photonics community and society at large. At ECOC, we are introducing a new booth design that showcases EPIC and the pilot lines we represent, such as Jeppix and Phabulous. There will also be an area open to all exhibitors, fostering connections between photonics companies and potential candidates, and strengthening their employer brand.

We care deeply about talent recruitment in the photonics community, and sustainability is a top priority for us as well. At our last meeting, it became clear that sustainability interests among participants were diverse. We have categorized them into the following:

- Sustainable photonics,
- Photonics for sustainability,
- Developing recyclable or upgradable products,
- Social and human aspects of sustainability, and we will delve into them in the future.

The importance of the 17 United Nations sustainable development goals is something we also want to emphasize. In response to our members' input, we believe there is a pressing need for a stan-

Upcoming EPIC events:

- 1 September 2023
  EPIC HR Workgroup Meeting: hiring outside Europe
- 6 – 7 September 2023
  EPIC Technology Meeting on Photonics in Defense, Kielce, Poland
- 7 September 2023
  EPIC TechWatch at CIOE on Optical Components, Materials and Innovative Applications, Shenzhen, China
- 18 September 2023
  EPIC Online Technology Meeting on Hybrid Photonics Integration
- 2 October 2023
  EPIC VIP Networking Reception at ECOC, Glasgow, Scotland
- 4 October 2023
  EPIC TechWatch at ECOC, Glasgow, Scotland
- 9 October 2023
  EPIC Online Technology Meeting on Optical Metrology Solutions for the Industry
- 11 – 12 October 2023
  EPIC Technology Meeting on Industrial Quantum Photonics Technology at Toptica, Munich, Germany
- 16 October 2023
  EPIC Online Marketing Meeting: Google Analytics I – unlock the power of GA4
- 21 October 2023
  Day of Photonics

For the list of all events, visit:

www.epic-assoc.com/epic-events

dard sustainability policy document specifically tailored to photonics companies. We aim to work collaboratively within our community to develop and approve this document, using it as an industry benchmark. If you want to be part of the green wave, join our next Sustainability Working Group Meeting on 6 October.

Remember: 21 October is the Day of Photonics when every company, school, organization, association, university, and individual is invited to participate!

www.epic-assoc.com

New Chairman of VDMA Measuring and Testing

The board of the association has elected Marcus Korthäuer of Espera-Werke in Duisburg

Dr Marcus Korthäuer succeeds Dieter Menne, who retired from active professional life at Mettler Toledo in the middle of the year and therefore relinquishes the chairmanship of the trade association.

Korthäuer has been a member of the board of the Measuring and Testing Technology Association within the VDMA since 2016 and also chairs the advisory board of scale manufacturers. In addition to his expertise as managing partner of a medium-sized, internationally active manufacturer of price and weight labeling systems, he brings extensive experience from honorary activities in business and employer associations as well as in the European scale association CECIP to the board's work.

He is particularly concerned with strengthening the competitiveness of German industrial companies in international comparison and reducing the burdens of bureaucracy in Germany and Europe.

In addition to the optimization of processes, the digital networking of measurement and testing components, machines and systems in production is for him both a challenge and an opportunity for manufacturers and customers.

"A big thank you goes to Dieter Menne, who has led the Measurement and Testing Technology Association since its founding in 2012 and successfully managed the merger of three formerly independent industry associations into one organization," Korthäuer said.

Dr Marcus Korthäuer, managing director of Espera-Werke (Source: VDMA)

www.vdma.org

Longtime treasurer says goodbye

AMA starts the next administrative period with new treasurer and proven team on the board

In May, the general meeting of the AMA Association for Sensor and Measurement elected its board of directors in rotation for the next two years. The AMA members confirmed the re-election of the current board for the next period: Peter Krause (Prignitz Mikrosystemtechnik and Insenso) as chairman of the board, Christoph Kleye (SonoQ) as vice chairman, Rolf Slatter (ITK Dr. Kassen) as secretary. The two assessors Stefan Zimmermann (Leibnitz University Hannover) and Thomas Simmons (AMA managing director) will also remain in office for another two years.

Long-time treasurer Johannes Steinebach did not stand for re-election but recommended his son David Steinebach (TWK Elektronik) as his successor. The AMA general meeting followed this recommendation and elected David Steinebach as the new AMA treasurer.

"We would like to thank the members for their trust in our work and we will continue this with great commitment. We welcome David Steinebach as a new board member and look forward to new impulses through rejuvenation. We would like to express our special thanks to Johannes Steinebach. He shaped the AMA Association for twenty years as treasurer. He was and is a great comrade-in-arms for us professionally and personally, in good and in turbulent times. We are pleased that he will continue to support our work as a member of the AMA Council of Elders. For this, we thank Johannes Steinebach on behalf of the AMA members and the entire board," said Peter Krause, previous and re-electedAMA board chairman.

(l – r) Thomas Simmons, Rolf Slatter, Christoph Kleye, Stefan Zimmermann, Peter Krause, David Steinebach (Source: AMA / Bischof & Broel)

www.ama-sensorik.de

History, present, and future

124th annual conference of the German Society for Applied Optics (DGaO) in Berlin

On the ceremonial occasion of the 100th anniversary of the founding of the DGaO, conference chair Prof Dr Dirk Oberschmidt invited guests to the Technische Universität Berlin in the city where the society was founded one hundred years ago. The special conference venue provided an excellent setting to celebrate, reminisce, discuss current research topics, and look at future issues of technical optics.

A total of 84 technical papers were presented in 17 sessions. The main topics of the day were introduced in six keynote lectures. Prof Oberschmidt (TU Berlin) presented an outline of the various research topics of his department with his lecture on the processing of different materials for optical components. Dr Ralf Jedamzik (Schott) provided fascinating insights into the history of optical glass and its industrial production with the help of glass diagrams from different decades. Dr Henning Rehn (Fisba) presented important aspects of energy conservation and the function of illumination optics with the presentation of phase diagrams in illumination optics. Prof Bernd Jähne (University of Heidelberg) explained in his lecture the further development of linear camera models towards more general models and discussed their relevance in camera selection for specific applications. Bernd Dörband illustrated the development of interferometry and its relevance, for example from the confirmation of Einstein's theory of relativity up to being a key technology in the semiconductor industry. Frank Siewert (Helmholtz Zentrum Berlin) showed how the development of modern radiation sources on the one hand drives the demand for optical elements, but also enables novel experiments. Prof Stephan Völker (TU Berlin) presented how research for modern traffic lighting addresses current trends such as the reduction of light pollution and safety risks.

The conference in the H 0104 in the main building of lecture hall at Technische Universität Berlin (Source all images: DGaO)

In addition to the presentations, there was also a poster session with lively discussions on a total of 33 posters. The prize for the best poster went to Anja Bartelmei (Fraunhofer IOF) on the concept and design of a multi-aperture 2π panoramic camera.

On the occasion of the 100th anniversary of the founding of the DGaO, there was a special colloquium on historical topics on Friday. Gerd Häusler and Rainer Schuhmann took us through the history of the society, also highlighting the connection to the Optical Institute of the TU Berlin. Besides some at times surprising historical facts and backgrounds, various photos and anecdotes from the different decades provided plentiful entertainment. Afterwards, Peter Karbe presented the development history of Leica's apochromat photo lenses with sectional views and systematic analyses. The colloquium was rounded off by Marvin Bolt and Michael Korey with a vivid description of their – in part quite surprising – research on historical telescopes.

After all these historical topics, the 'Nachwuchspreise der DGaO' are firmly rooted in the present and point beyond it into the future. The prize for the best diploma thesis was awarded to David Krause (TU Dresden). He contributed to the determination of the transformation matrix of multimode fibers, which

The 'Nachwuchspreis' winners David Krause (left image, center) and Babak Zandi (right image, center) with Ricarda Kafka and Prof Andreas Heinrich, respectively

is essential for the use of these fibers in secure communication networks. The prize for the best doctoral thesis was awarded to Babak Zandi (TU Darmstadt), who further developed the modelling of physiological vision with respect to the dynamics of the pupil diameter and its dependence on the spectrum of different light sources.

Currently, a worrisome decline in the number of first-year students in optics as in all STEM subjects is seen. There were two special program items at the conference to address this problem. The 'DGaO-Nachwuchsförderung' put together a session entitled "Inspiring young people for optics!". Ideas and experiences were shared in five contributions on how to successfully address schoolchildren today to spark and promote interest in optics. For example, optics kits, a digital-remote lab or a mobile photonics lab were presented. Diverse career paths in optics that are interesting for students and graduates were considered in a panel discussion.

This year's general assembly of the DGaO voted for RWTH Aachen as the conference venue in 2024. As a result, Prof Carlo Holly (Optical Systems Technology) will be next year's conference chair. Afterwards, Prof Gerd Häusler and Dr Rainer Schuhmann were appointed as new honorary members for their various contributions and many years of service to the DGaO. Stefan Bäumer (principal scientist of TNO) pointed out their diverse accomplishments in a well-worded laudatory speech.

To conclude this report, a few points of the extensive and varied social program should be mentioned. As part of the welcome reception on Tuesday evening, Prof Timo Mappes gave a lecture on the conception, reconstruction and exhibits of the German Optical Museum in Jena. On Thursday there was an inspiring and very entertaining science slam before the conference attendees gathered on the banks of the Spree for a river cruise. A boat took us along the waterways of the city of Berlin. The Westhafen, the Kanzleramt and Museumsinsel are just a small selection of the city's special places. There were good conversations in the most beautiful evening sunshine on the upper deck, and of course a rich buffet.

At this point the DGaO would like to thank Prof Dirk Oberschmidt and his team. The society experienced very good organization and implementation of the event. The technical discussions and the supporting program were excellent. Some surprises in the course of events were professionally mastered. With these good impressions, the DGaO is looking forward to next year's conference at the RWTH Aachen, where preparations by Prof Holly and Nicole Grubert are in full swing.

https://dgao.de

SPIE welcomes 89 new Senior Members in 2023

The society honors and recognizes scientific excellence and technical achievements, as well as active participation in the optics community

The international society for optics and photonics SPIE has welcomed 89 new Senior Members from 17 countries. The newly recognized individuals – drawn from across academia, industry, and government – work in a variety of disciplines that include nanophotonics, quantum optics, biomedical engineering, free space optical communications, microscopy, optical systems engineering, medical imaging, lidar, machine learning, optoelectronic devices, microstructured optical fiber technology, astronomical optics, and lithography.

SPIE Senior Members are society members of distinction who are recognized for their professional experience and technical accomplishments, their active involvement with the optics community and with SPIE, and for significant performance that sets them apart from their peers.

Among the new cohort, the society welcomes a strong representation of women from across the globe, including Rosalind Wynne, director of the Laboratory for Lightwave Devices at Villanova University and an active member of the SPIE Smart Structures community; Imrana Ashraf Zahid, of Quaid-i-Azam University and the first woman in Pakistan to gain a doctorate in quantum optics; Saša Bajt, a group leader at Deutsches Elektronen-Synchrotron DESY; Misty Blowers, CTO of Datalytica; Teri Odom, a professor of materials science and engineering at Northwestern University; Ingrid Udd Scheel, president and founder of Multnomah Falls Research; and Jaione Tirapu Azpiroz, a senior research scientist at IBM Research in Brazil.

"I congratulate and welcome our new SPIE Senior Members," said Oliver J Myers, 2023 Senior Member Subcommittee chair, an associate professor and associate dean of inclusive excellence for undergraduate studies at Clemson University. "All of them are outstanding researchers, practitioners, and supporters of optics and photonics applications. Their invaluable technical contributions advance our field in innovative ways, and their active engagement with the wider community supports its greater development across the international stage. It is especially gratifying to increase the diversity of Senior Members and the spectrum of research in the optics community. I look forward to helping SPIE become more inclusive in the future."

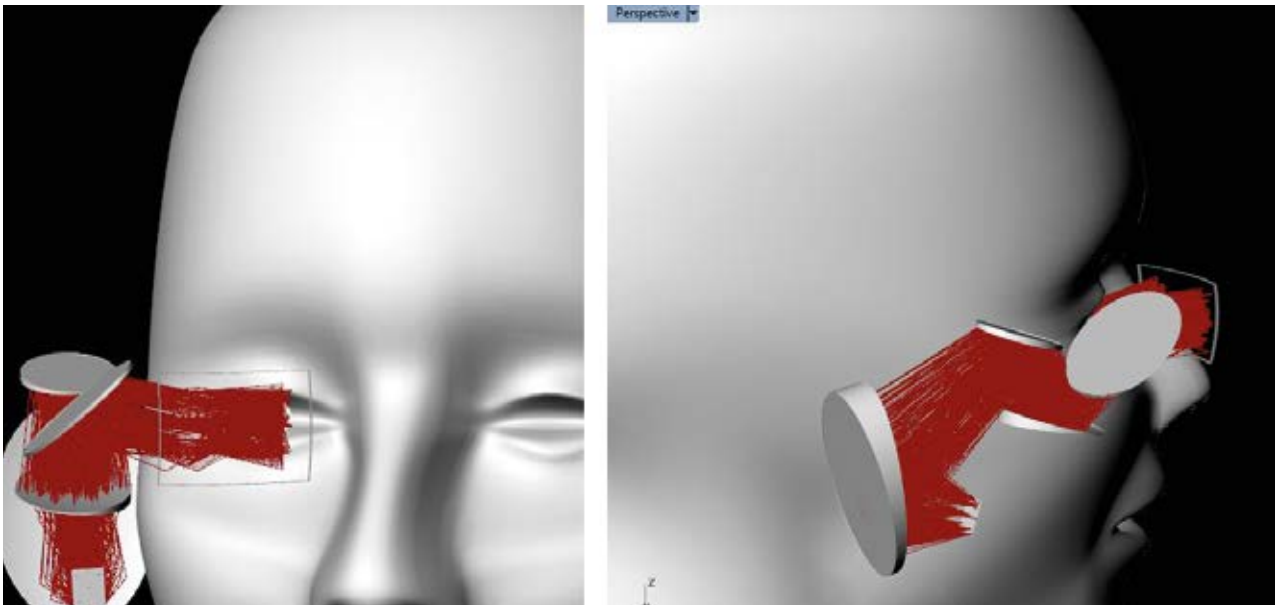
The laureates from industry include Richard Horton (Ad Hoc Optics), Mark Maslow and Abhishek Vikram (ASML Netherlands), Laura Coyle, Brian Hicks, Sarah Lipscy, and Garrett West (Ball Aerospace), Thomas Franz Karl Scheruebl (Carl Zeiss SMS), Xisen Hou and Mingqi Li (DuPont Electronics & Industrial), Henning Rehn (Fisba), Soichi Inoue (Kioxia), Jangsun Kim (Panoptics), Yusuf Bhagat (Pericycle), Jeffrey Nicholson (OFS Fitel), Paul Knutrud (Onto Innovation), Tyler Ralston (Oxford Nanoimaging), Uwe Petzold (Schott), Ingo Bork (Siemens EDA), Kent Nakagawa (Toppan Photomasks), and Wiley Black (Vizgen).

https://spie.org

XR unmasked

Exploring the complexities of design and simulation in extended reality

Jérémy Picot-Clémente



▲ An AR optical system designed in CODE V and shown in a CAD software package: front view (left) and side view (right; source: Synopsys)

As XR pushes the boundaries of immersive technology, the challenge of creating a flawless simulated reality presents unique design hurdles. In this critical analysis, we unpack the fundamental issues, identifying potential solutions and forecasting future developments in the XR landscape.

Extended reality (XR) applications, including virtual reality (VR), augmented reality (AR), and mixed reality (MR), are revolutionizing the way we interact with digital content. In healthcare XR has the potential to play a significant role in medical training, simulation, and patient care, while in education XR is revolutionizing the learning experience, providing students with immersive and interactive educational content. In the entertainment and gaming industry XR is continuing to redefine the way we consume media and interact with virtual worlds through fully immersive VR gaming experiences, mixed reality live events, and interactive storytelling. XR is also having an impact on the industrial sector by facilitating remote collaboration and training for workers in hazardous or remote environments and providing real-time remote assistance to support technicians in troubleshooting and maintenance.

The XR market

According to a market report on AR/VR/MR optics and displays, the global augmented, virtual, and mixed reality optics and display market is expected to be worth around US$ 29 B by 2030 [1]. Other reports are more optimistic predicting an increase in the whole XR market from US$ 18.4 B in 2022 to 457.1 B in 2030, a CAGR of 58.2 % [2]. The largest region will be North America followed by Europe, but the fastest growing will be Asia Pacific. As regards applications, the consumer demand for gaming and entertainment devices is expected to maintain its dominance, followed by the healthcare sector's requirement for high-resolution displays, e.g., for performing orthopedic surgery, neurological procedures, and cardiac surgery. The military and defense market is also expected to grow due to the demand for accurate coordinates and pictures via satellites.

Active users

According to figures from eMarketer 2022, the number of people in the US who use XR technology at least once a month will increase from 70.8 million in 2023 to 75.4 million in 2025; meanwhile, Meta say they have already sold nearly twenty million Quest headsets (US$ 300 – 500 depending on version). While these figures may seem impressive, using a technology once a month does not constitute active use and is not therefore a particularly lucrative business. The best indication of long-term market growth is the retention rate, i.e., the number of active users who return to the hardware/software market for a particular technology on a regular basis. Some in the industry claim that XR retention rates are below 10 % because gamers prefer to relax than be active and, compared with classic console gaming, VR still demands more active engagement and has more friction [3]. Wearing a VR headset is also more antisocial and the small successes with high nausea potential are scaring off the masses. For

these reasons, some argue that VR will not scale massively until these issues are resolved [4].

Accordingly, developers of XR technology are working to overcome various challenges in the design and simulation of XR applications in three main areas: real-world immersion, computational power optimization, and device constraints. This article explores these challenges and discusses potential solutions and future developments in the XR landscape to enhance user experiences and overcome these hurdles.

Challenges in the design and simulation of XR applications

Optimization of real-world immersion

One of the primary challenges in XR application design is achieving a high level of real-world immersion, i.e., the sense of presence and the feeling that users are physically present in the virtual environment. Firstly, designers need to pay meticulous attention to details such as lighting, textures, and spatial audio to evoke a sense of realism. Advanced rendering techniques, such as physically-based rendering (PBR) and global illumination, can enhance visual fidelity and contribute to a more immersive experience. Secondly, to ensure accurate spatial mapping and object occlusion, XR applications need to accurately map the physical environment to virtual space so that users can interact seamlessly with both real and virtual objects. Overcoming challenges related to occlusion, where virtual objects correctly interact with real-world elements, enhances immersion by avoiding visual inconsistencies. The third challenge in this area is that of simulating realistic physics and interactions. Accurate collision detection, object dynamics, and physics-based interactions contribute to a more believable and immersive experience, and implementing robust physics engines and optimizing computational algorithms are crucial to achieving realistic interactions in real-time.

Improvements in hardware

The development of lightweight and high-resolution displays is a high priority. Higher pixel densities, a wider field-of-view, and improved color accuracy are helping to create more realistic and visually stunning XR visuals. The integration of eye-tracking technology allows for foveated rendering – a device-performance optimization technique that concentrates rendering resources on the area of the display where the user is looking. This enhances overall visual quality and allows gaze-based interactions, enabling users to select objects, trigger actions, and navigate menus simply by looking at them.

Secondly, advancements in haptic feedback are providing users with a more immersive and tactile experience. Fine-grained hand tracking and gesture recognition algorithms can enable users to interact with virtual environments through natural gestures and movements, eliminating the need for physical controllers.

Thirdly, spatial audio technologies such as sound propagation algorithms and personalized audio profiles can create a more realistic and immersive soundscape, further enhancing the sense of immersion and spatial awareness. Advancements in voice recognition and natural language processing are enabling more seamless voice interactions, allowing users to control virtual objects, to navigate menus, and to communicate with virtual characters using just their voice, creating a more intuitive and immersive experience.

Computational power optimization

Achieving high-quality graphics, realistic physics simulations, and smooth interactions in real-time requires substantial computational power. In this regard, real-time rendering is a key computational bottleneck. Generating immersive visuals while maintaining high frame rates is essential for a comfortable and engaging experience. Designers must optimize rendering pipelines, employ efficient rendering techniques (level of detail, occlusion culling), and leverage hardware capabilities (graphics processing units) to achieve smooth and visually appealing XR content.

A second challenge is the optimization of physics simulations that also demand significant computational resources. Implementing efficient physics engines and utilizing parallel computing techniques can help to optimize real-time physics simulations, ensuring smooth and realistic interactions. Efficient data management and streaming are also critical: large datasets, including high-resolution textures, 3D models, and audio files, need to be processed and streamed seamlessly to XR devices.

Source: Dispelix

Dispelix supplies elegant, see-through XR displays in a minimalistic eyeglass form factor that enable XR glasses providing a comfortable user experience.

Optimizing data compression, streaming protocols, and network bandwidth utilization can minimize latency and provide uninterrupted XR experiences.

Device constraints and compatibility

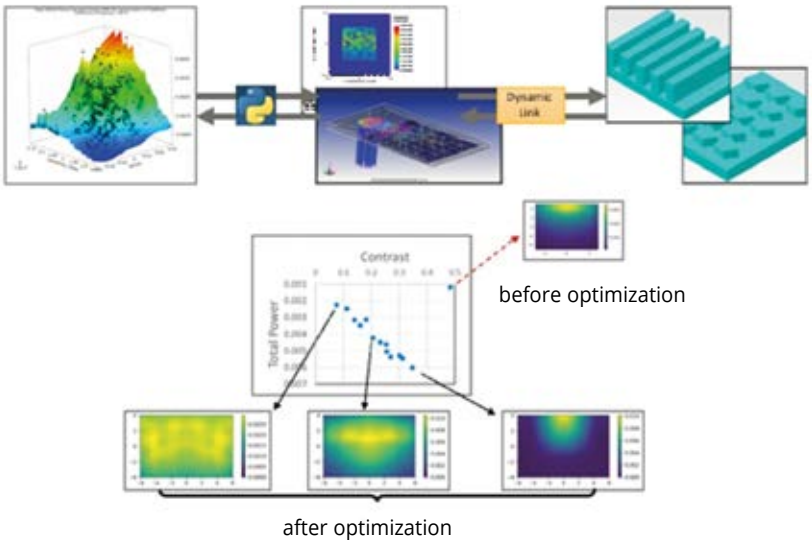
Considerations for device compatibility are crucial to reach a broader user base, maximize the impact of XR applications and provide users with more consistent experiences regardless of the device, platform, and OS. To achieve this, designers need to adapt content to different devices and resolutions to ensure optimal visual quality and minimize distortions. Employing adaptive rendering techniques that dynamically adjust the graphics quality based on device capabilities can help to address these challenges, as can creating flexible and intuitive interaction mechanisms and application interfaces that accommodate different input methods, such as hand gestures.

Commercialization of XR technology

The following are examples of companies currently addressing these challenges for XR in software, design and simulation, and design and manufacturing.

Software

US-based Ansys Optics provides the industry-leading suite of multiphysics software solutions for the design of advanced XR systems, with capabilities ranging from the nanoscale to



The design optimization tool Ansys optiSLang can connect different physics algorithms. Component-level optimization of gratings and lenses can be conducted based on system-level metrics of image quality and user experience. (Source: Ansys)

the scale of human perception. From light engines to the diffractive waveguides used in coupling light from the source to the eye box, Ansys Lumerical enables design at the wavelength and subwavelength scale. They employ robust finite difference time domain methods (FDTD) complemented with rigorous coupled wave analysis (RCWA) that excel at the fast and accurate modelling of periodic structures. Ansys Zemax models the macroscopic optics used in XR designs, from the lenses that couple light from the waveguide into the human eye to the eye-tracking cameras that optimize performance and eliminate the need for exterior controls. At the scale of human perception, Ansys Speos enables the comprehensive modelling of the optomechanical system, including the impact of unintended stray light on system performance. This software contains unique algorithms for human vision simulation that enable engineers to simulate the end user's perception of the augmented or virtual reality display with realistic illumination conditions. The seamless integration and interoperability between these tools powers the Ansys Optics product portfolio, enabling streamlined design workflows. With design optimization tools like Ansys optiSLang, which can connect different physics algorithms together, component-level optimization of gratings and lenses can be conducted based on system-level metrics of image quality and user experience.

Synopsys, an electronic design automation company headquartered in California, provides a complete set of tools to develop AR/VR/MR systems, from optics to microelectronics and from design to manufacturing simulations. This portfolio includes CODE V for imaging optics design and tolerancing, LightTools for stray light analysis and waveguide combiners optimization, and RSoft Photonic Device Tools for microdisplay and holographic and diffractive gratings design. It also includes their TCAD (technology computer-aided design) portfolio with the Sentaurus suite of tools, embracing electro-optical devices and manufacturing process simulations.

As the company points out, XR systems are pushing the limits of optics to the extreme in terms of miniaturization, cost, and performance, as well as having a need for a seamless simulations portfolio to create and optimize disruptive imaging systems, analyze parasitic light in the optical path, and design and anticipate the manufacturability of meta optics, diffractive or holographic optical combiners.

Belgium-based PlanOpSim provides a start-to-finish workflow for the design of meta-lenses and other meta-surfaces, providing AR/VR designers with the key tools to get the maximum benefit out of metasurfaces – including system integration and capabilities for large area metalens/metasurface design. This multiscale simulation enables high speed calculations, a crucial aspect in speeding up R&D iterations and improving time-to-market.

PlanOpSim is one of the frontrunners in recognizing that such complex hardware-software devices benefit from building bridges between tools, such as between ray optics and wave optics tools. In this regard, the company has recently launched an integration for well-known ray-tracing programs that provides an integrated workflow and lets optical engineers focus on the design itself instead of the nuts-and-bolts of patching together different software tools. PlanOpSim can also offer insights into design-for-manufacture, thereby creating the opportunity to compensate for fabrication defects in metasurface design.

Design and simulation

Israel-based Joya Team is an optical design house that specializes in AR and VR optical design and development, supporting startups from the initial idea stage to product scaling. With a dedicated team of optical engineers, physicists, and optical designers, they bring extensive experience in the field of XR. As pioneers in optics for AR, VR, and XR, the team's focus is on addressing the challenges associated with designing and simulating cutting-edge optical solutions for immersive applications. By leveraging their expertise in real-world immersion simulation and display technologies, Joya Team optimizes optical systems while considering trade-offs in use-cases, user experience, and performance.

Scivax, a company based in Japan, are mainly producing two products: 'Better than DOE optics' for 3D sensing illuminator by original optical simulator mixing Maxwell's equation law and lay tracing, and ultrafine nanoimprint technology. One is Platanus diffuser which has a highly controllable field of illumination (FOI) from 1 to 140 degrees and flexibility for aspect, light profile, and others, matching to high resolution time of flight (ToF) 3D sensing. On the other hand, Ardisia can create a dotted pattern without a collimator lens. By concentrating light power into dots, the measurable distance becomes longer over ten meters and ultralow power driving is enabled at the same distance for a diffuser. By combining the two optics, Scivax is confident of opening a new era for AR/VR/MR systems. With a combination of ToF and a color image sensor, 3D images with color can be captured in real time. The cutting-edge lenses should lead XR developments.

Ansys Speos contains unique algorithms for human vision simulation that enable engineers to simulate the end user's perception of the augmented or virtual reality display (Source: Ansys)

Design and manufacturing

Finnish company Dispelix, develops and delivers waveguide combiners while outsourcing fabrication to nanophotonics foundries. The company supplies elegant, see-through XR displays in a minimalistic eyeglass form factor that enable XR glasses providing a comfortable user experience. As they point out, any commercially viable XR concept must meet image quality expectations set by the high bar of today's advanced smartphone displays. For Dispelix, this translates into single-layer waveguide combiner designs with uncompromised performance and image quality. The design of diffractive optical systems is extremely computing intensive, which requires the right software tools to tackle the challenge.

They understood early on that waveguide design must be mastered to be successful in the fiercely competitive field of XR. Accordingly, they have invested heavily in algorithm development and in-house design capability, and their in-house design tool provides a rigorous physical model of a diffractive optical waveguide system.

This simulation tool also considers the phase of the light and therefore includes interference effects occurring in the waveguide. The tool can solve complex, multiobjective optimization problems fast and efficiently. Human-centric vision model and manufacturing tolerancing are incorporated in the Dispelix tool, which is compatible with high-performance computing clusters.

A new modeling software tool called PanDao, a company based in Switzerland, has been developed that enables the integration of producibility analyses and fabrication chain optimizations into the optical design process. PanDao reads in lens data as described in the ISO 10110 standards and determines the optimal fabrication chain at minimum cost and risk, taking more than 360 optical fabrication techniques into account. Consequently, PanDao can be used for cost impact analyses during the design stage as well as for the optimization of supply chain management, for example in identifying optimum suppliers.

Future developments in the XR landscape

As we have seen, XR has enormous potential to transform numerous industries, particularly entertainment and gaming, healthcare, education, and the industrial sector. But the successful future of XR heavily will rely heavily on increasing the number of active users and thereby retention rates for the technology. This in turn will depend on the ability of developers to improve user experience by providing a higher level of real-world immersion and more lightweight, higher-resolution and less socially-isolating displays. But perhaps most important is the need to create flexible and intuitive interaction mechanisms and application interfaces that guarantee consistent high-quality user experiences regardless of the device, platform, and OS.

Another challenge for the future of XR is cost. However, as XR hardware becomes more advanced and affordable, cost is likely to become less of a barrier as evidenced by Meta's latest VR headset, the Quest 3, which retails at around 500 dollars, considerably less than a good smartphone.

In terms of mobile applications, AR has been more widely adopted than VR because AR can be used on a wide range of devices, while VR typically requires specialized hardware such as a headset. But despite the current limitations of VR for mobile applications, the potential for this technology is enormous. With the increasing power of smartphones, it is likely that VR will become more accessible and more widely adopted in the future. In addition, the development of 5G networks will enable faster and more stable connections, making it possible to create more complex and immersive VR experiences on mobile devices.

Finally, issues with data security and privacy will need to be addressed. As XR technology becomes more integrated into our lives, developers will need to prioritize privacy and security in order to minimize the threat that personal data will be collected and misused.

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[1] Precedence Research June 2022 Market report on AR/VR/MR Optics and Display Market. https://www.precedenceresearch.com/augmented-reality-virtual-reality-mixed-reality-optics-and-display-market
[2] Market Report Future https://www.marketresearchfuture.com/reports/extended-reality-market-8552
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Author

Jérémy Picot-Clémente is a physicist specialized in optics and a program manager at the European Photonics Industry Consortium (EPIC). After a PhD in physics/optics and an MBA, he decided to explore the industry for several years through various missions in managing photonics systems integration, for several applications and in different companies. At EPIC, Jérémy is in charge of the development of the optics and micro-optics fields, and all related technology and applications. He has a strong interest in new technology involving photonics, such as AR/VR, lidar, 3D sensing and imaging devices.

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A small country with high ambitions

The Lithuanian laser industry – 40 years of innovation

Gediminas Račiukaitis and Kristina Ananičienė

Source: Light Conversion

Starting from fundamental research just after the discovery of the laser, the Lithuanian laser industry is celebrating forty years since the first commercial company, Eksma, was established in 1983 to produce picosecond lasers. The sector has grown into a fully self-sustaining ecosystem, providing optics, ultrashort-pulse lasers, laser technology and systems to the global market. Today, lasers and optics are one of Lithuania's strongest and highest value-added industrial sectors.

A short excursus back, reflecting on the most frequent question of why Lithuania is so strong in lasers: in 1960, the laser was among a number of new scientific discoveries that emerged, and the first laser was fired in Lithuania just six years later. Eksma was established in 1983 to produce picosecond lasers and we are now celebrating forty years of the laser industry in Lithuania. The laser sector is a significant high-tech industry for Lithuania, allowing the country to make its mark internationally. The reason is the strong cohesion between R&D activities in laser companies and the academic research centers that has enabled Lithuania to gain and maintain a leading position in the global market.

Laser physics and applications coexist all the time in Lithuania. That is an active dipole charging the whole laser community to new discoveries in lasers and laser applications. The last two decades were marked by intensive penetration into the industrial laser market. This segment is represented not only by reliable 24/7 ultrashort-pulse laser sources as tools for delicate material processing; today we have a full-value chain of laser technologies in Lithuania – from optical coatings to laser workstations and beyond. Solid expertise has been collected in laser microfabrication with ultrashort pulse lasers. The output is laser processing technology and systems that are used in the electronic, consumables or automotive industries.

Laser and photonics sector and the competencies

The Lithuanian laser and photonics industry numbers about sixty companies; more than half of them are members of the Lithuanian Laser Association. Thirty Lithuanian laser companies presented their photonics components,

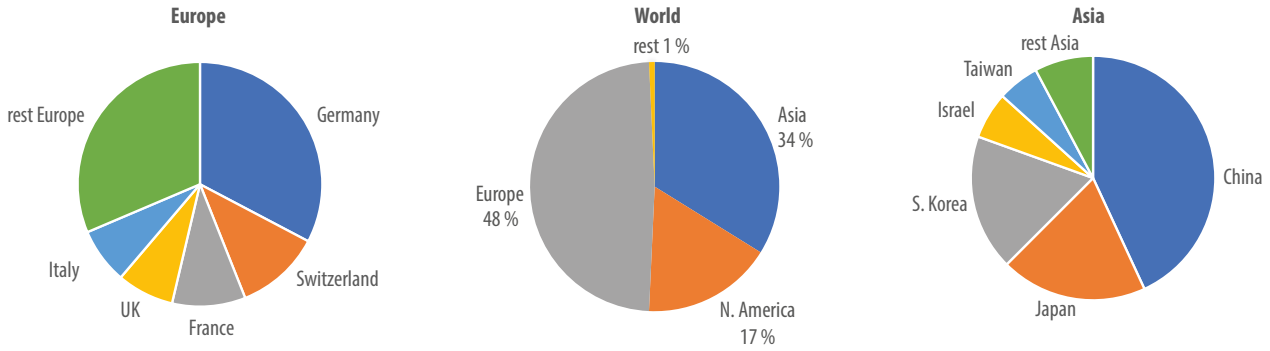

Fig. 1 Share of laser and optics market by countries in the period 2019 – 2022

systems and applications at this year's Laser World of Photonics in Munich. Close to twenty Lithuanian companies are active members of EPIC – European Photonics Industry Consortium. The LITEK and TOOLas clusters are part of the laser and photonics ecosystem, accelerating new companies and promoting photonics-related solutions for industry digital transformation.

The key competencies of Lithuanian laser and photonics companies are spread right along the value chain:

- components (optical coatings, optics and optical systems, opto-mechanics, high-power electronics),
- laser sources (reliable 24/7 ultrashort-pulse lasers for industry, high-intensity TW and PW class lasers, tunable wavelength laser devices),
- laser technology for material processing, including equipment for laser processing and laser-based services.

In addition, we have competencies in laser systems for nonlinear spectroscopy, optical and quantum communication and optical measurements. An emerging area is laser systems for medical diagnostics and therapy.

How well do we perform on the global market?

Today, the Lithuanian laser sector provides more than 1,600 highly skilled jobs with an added value per employee that is more than three times larger than the national average. The impressive growth of the laser industry of 16.2 % CAGR has continued from 2009 through 2022, ten times higher than the average industry in Europe. Even in turbulent times, our sales grew by 21 % in 2022, amounting to 210 million euros. Half of the revenue comes from the industrial market, a consequence of active penetration into new markets. Rapidly growing activities in laser material processing and improvements in laser technology have allowed Lithuanian laser products to enter the industrial market. Expansion of the community to more than sixty companies took place, mainly by spin-offs from research laboratories, broadening the spectrum of laser and photonics products and applications. Despite its modest size, the country is a global player in both scientific and industrial laser technology, exporting laser solutions to over eighty countries and partnering with the likes of NASA, CERN and ELI.

Europe, with leader Germany, remains the most important and rapidly growing market for Lithuanian lasers and optics (Fig. 1). Scientific as well as industrial applications are equally represented. Exports to Germany increased 2.4-fold, and to Switzerland three-fold in a three-year period (2019 – 2022). Growth is visible for the UK market, while sales to France and Italy are fluctuating. The strength of Europe as a laser technology provider is supported by high-quality optics and reliable laser sources made in Lithuania. Therefore, in most cases, Europe is not the final destination of our products.

The North American market for our lasers, components and technologies is growing as well and is dominated by the USA. The Asian market is dynamic, reflecting a mixture of political, pandemic and economic disturbances (Fig. 2). The 'world's factory', China, is important for scientific as well as industrial lasers since the main manufacturing facilities for consumables and electronics are still working there. The decline in sales to China from 2020 was compensated by significantly higher demand for our lasers and optics in Japan, South Korea, and Taiwan. The recovery of the high-tech industry in

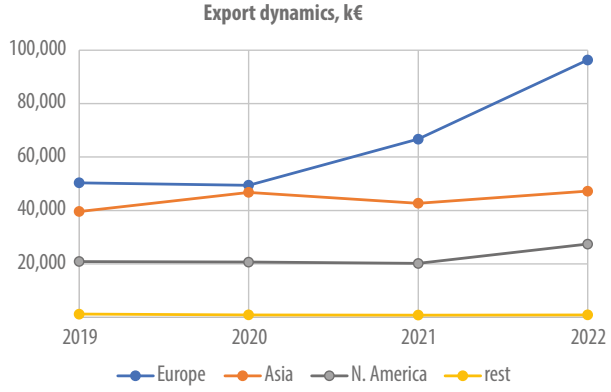

Fig. 2 Export dynamics in years 2019 – 2022.

Association

Lithuanian Laser Association

The association was established in 2004, bringing together academic institutions and companies to road-mapping their activities in the field of 'photonic and laser technologies' – one of the Lithuanian Smart Specialization priorities. Lobbying at the national level and representation internationally are what we are doing for the benefit of our members. The association currently numbers 31 companies together with the academic members Vilnius University and FTMC.

www.ltoptics.org

Japan is visible as more ultrashort-pulse lasers and optics are ordered.

We are rediscovering the leading manufacturing markets (South Korea, Taiwan), where the most advanced semiconductor chip and consumer electronics manufacturing is concentrated. There is significant interest in Lithuanian lasers from Taiwanese high-tech companies. We will therefore open a laser demo center at the Industrial Technology Research Institute in Taiwan this September. The opportunity to be closer to users of our technology should facilitate deeper penetration into the supply chain of equipment for the semiconductor, electronics and consumer markets.

Targeted market segments and applications

The products of the Lithuanian laser sector are extremely diverse. The whole value chain of an optical component starting with a piece of glass manufacturing, advanced optical coatings with multiple dielectric layer deposition to mechanics and electronics fabrication is aligned. There are four key competencies of our laser sector – reliable industrial ultrashort pulse lasers, high-intensity petawatt and terawatt class lasers, tunable wavelength lasers, and semiconductor lasers for mid-IR. Applications of ultrashort-pulse laser technologies in semiconductor, electronics, optical and quantum communication, consumer and biomedical fields have been prioritized.

The scientific laser market is a historically strong point for the Lithuanian laser industry. Due to the impressive scientific expertise of researchers and engineers in new, beyond-the-state-of-the-art product developments, 95 out of the world's top 100 universities are using lasers made in our country. Lithuania is among the founding members of ELI – Extreme Light Infrastructure – together with Italy, Hungary, and the Czech Republic. Lithuanian companies Light Conversion and Ekspla have produced the high-intensity OPCPA ultrashort-pulse lasers for ELI facilities.

Laser machines and technologies are a promising market for our products, and the companies and the Lithuania Laser Association work intensively to increase our visibility in global markets. The integrated value chain from components to laser machines with technology is a peculiarity of the Lithuanian laser community. A group of companies, Akoneer [1], Femtika [2], and Workshop of Photonics [3], together with researchers at the Vilnius University and FTMC, develop technology for microfabrication, utilizing advances provided by ultrashort-pulsed lasers: from laser-based service to complete laser machines for the factory floor.

The Lithuanian laser sector is diversifying to other market segments, including biomedical, sensing, and optical communication. The new products in the biomedical field are dedicated to therapy like eye surgery, photoacoustic imaging, skin treatment and nonlinear microscopy. Research is ongoing on therapy and medical diagnostics using laser-induced secondary radiation (X-ray, gamma, proton). For medical applications such as stent therapy (especially in coronary heart disease), catheters, intraocular lenses etc., ultrashort-pulse lasers are used where the highest microprocessing quality is needed.

Lyncis provides industry-proven systems utilizing laser-induced breakdown spectroscopy (LIBS) for the automatic continuous chemical analysis of ore grade sorting in mines. Specialized lasers from QS Lasers, Optogama, Integrated Optics, and Quantum Light Instruments are used in remote sensing, lidar and pollution monitoring. Brolis Sensor Technology has developed a milk quality control system based on mid-IR spectroscopy.

Quantum technologies mostly use lasers for secure communication and sensing. A fresh start-up, Astrolight, is expanding fast in free-space optical and quantum communication.

Outlook

Starting our fifth decade of the laser industry in Lithuania, we are looking at all opportunities where lasers, optics and photonics can help in the fight against climate change, enable green manufacturing, and contribute to human well-being.

DOI: 10.1002/phvs.202300031

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Kristina Ananičienė, the executive director of the Lithuanian Laser Association, has been actively working with the Lithuanian laser community for almost a decade, promoting R&D&I activities and knowledge transfer, searching for R&D and business connections and partnerships. She is an experienced project manager, leader and a team-player, and manager of the Laser & Engineering Technologies Cluster LITEK.

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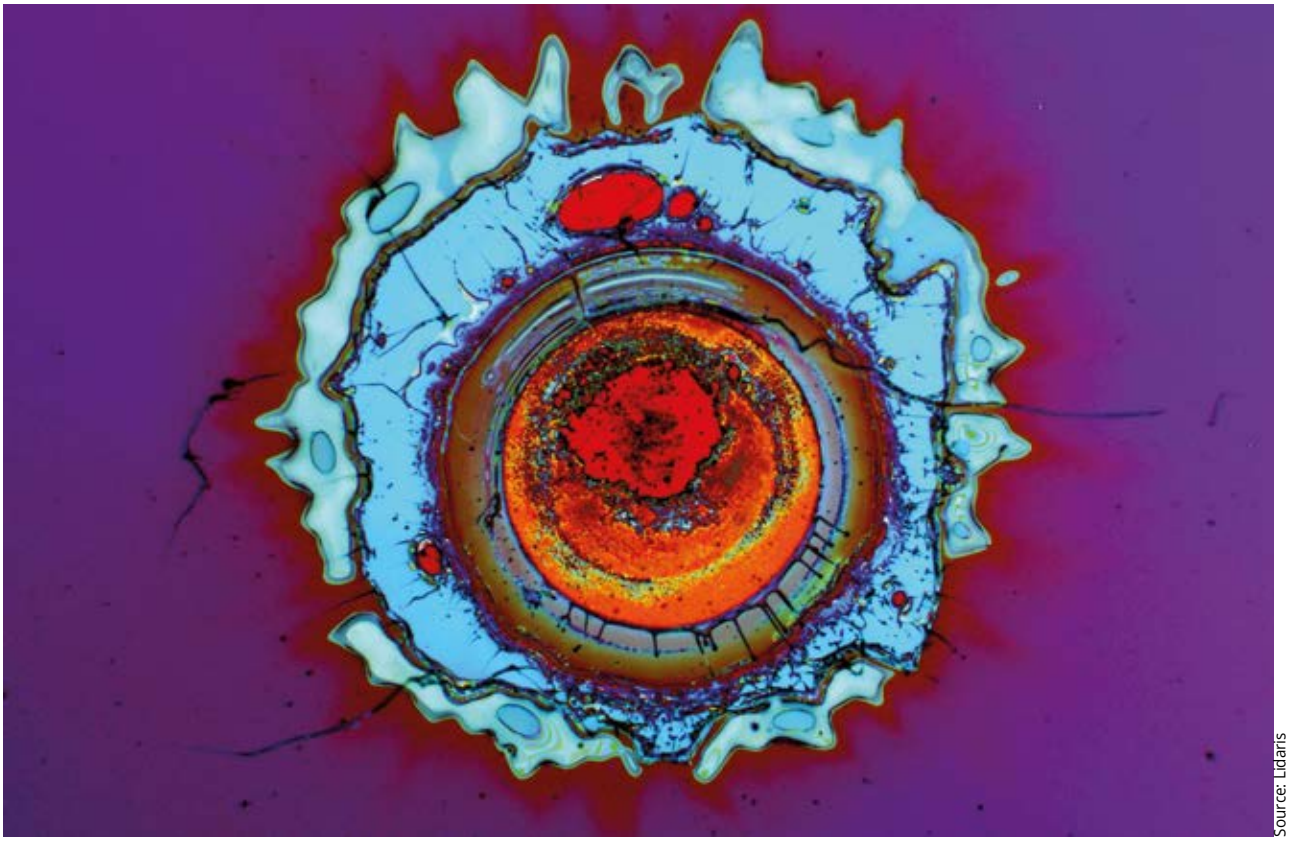
Ensuring permanence of optics for ultrafast laser applications

Low absorption dielectric coatings and their degradation prediction up to a billion laser pulses are the recipe for reliable long-lifetime optics in high-power ultrafast laser applications

Lukas Ceizaris & Gintarė Batavičiūtė



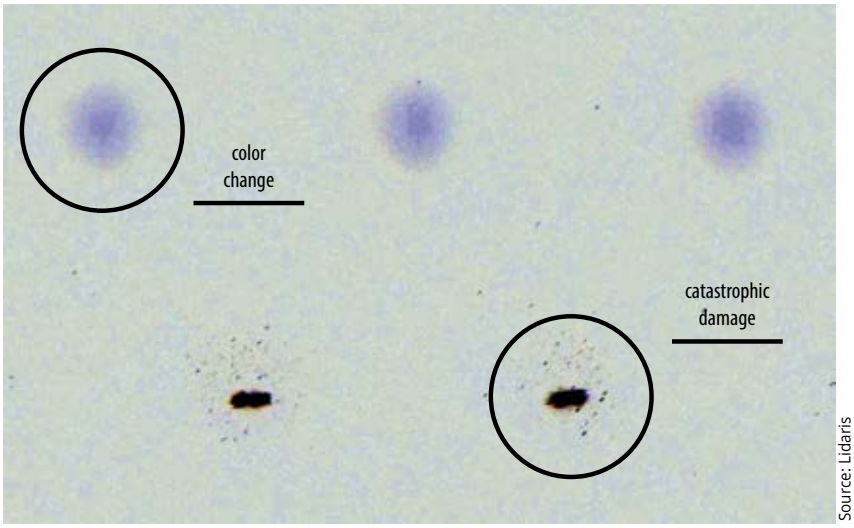
Source: Lidaris

Ultrafast lasers in various applications suffer from short lifetime optics due to high power levels and intense pulses. Typical laser damage testing methods are often limited to short exposure doses, which sometimes do not match real-life application requirements. To ensure long-term failure-free operation, lifetime estimation and low-loss absorptance testing should be used instead. Low-absorption dielectric coatings increase the lifetime and lower the total cost of ownership, benefiting the manufacturing, research, and medical sectors.

Ultrafast lasers, such as Ti:Sapphire, Yb:YAG, Yb:KYW/KGW or Yb-doped fiber lasers that generate pulses with durations down to a few femtoseconds, have opened up a new chapter in various fields. Industrial manufacturing applications such as material processing, precision machining, and micro structuring greatly benefit from ultrafast laser developments. Scientific research fields such as multiphoton microscopy and attosecond physics are also driven by ultrafast, high average power lasers. Many medical applications, such as ophthalmology, dermatology, and noninvasive surgical procedures, also employ high-power ultrafast lasers.

Ultrafast lasers operate at high power levels and generate intense pulses, putting significant strain on the optics. The field of ultrafast laser optics faces significant challenges in maintaining optimal performance and longevity. Short-lifetime optics lead to performance degradation, reduced efficiency, production downtime, and frequent maintenance work, significantly reducing the laser system's duty cycle. Enhancing the lifetime of optical components can notice-

▲ **Fig. 1** Differential interference contrast microscopy image of laser-induced damage on the dielectric coating.



Source: Lidaris

Fig. 2 DIC microscopy images of different laser-induced damage failure types (failure mechanism) induced on the dielectric coating. Material modifications (color changes) are visible on the top row. Catastrophic laser-induced damages are visible at the bottom.

ably lower the total cost of ownership because optics maintain the same performance over an increased amount of time, ensuring uninterrupted manufacturing operations.

Addressing the challenges of short-lifetime optics in high-power, ultrafast applications is crucial to unlock their full potential and ensure sustainable advancements in various industries. Rigorous testing is a pivotal part that provides transparency and reliability to the ultrafast laser user and enables optics manufacturers to ensure high batch-to-batch repeatability for long-lifetime optics.

For years, optics' ability to withstand intense laser irradiation was associated with the so-called laser-induced damage threshold (LIDT). It defines a safe yet efficient limit to operate laser systems without the failure of optical elements. Laser-induced damage threshold metrology is outlined in a set of ISO 21254 -1, 2, and 3 standards. The ISO S-on-1 procedure is probably the most popular testing option – a de-facto industry standard to report the typical LIDT values. It is a destructive measurement technique. The sample surface is divided into a virtual matrix of sites to be tested. Each test site is visually expected under the microscope prior to laser exposure. The test sample is then inserted into the LIDT measurement setup. A fixed number of sites (set of sites) is selected to be tested at various preset laser irradiation levels. Each test site from the set is exposed to a burst of laser pulses (S) with fixed laser peak fluence. During irradiation, the sample is monitored for damage: if damage is detected, the irradiation is stopped and the dose required to trigger damage is recorded. Otherwise, if samples survive a maximum number of S laser pulses, irradiation is stopped for that test site.

After exposure, the status of all test sites is also inspected with offline microscopy. Collected damage statistics are then used to calculate the so-called characteristic damage curve (CDC), which defines LIDT dependence versus the number of applied laser pulses (exposure dose). However, typical LIDT testing is usually limited to irradiation lasting only a few seconds or minutes, usually up to a thousand laser pulses per site or even less. Unfortunately, this does not always match real-life application requirements. In practice, it is important to guarantee months or years of uninterrupted operation of ultrafast

> Beware of the deceptive beauty of laser damage. While it may look mesmerizing, nobody wants to encounter it firsthand. It doesn't matter how strong and fast your laser is it is only as durable as its weakest link.

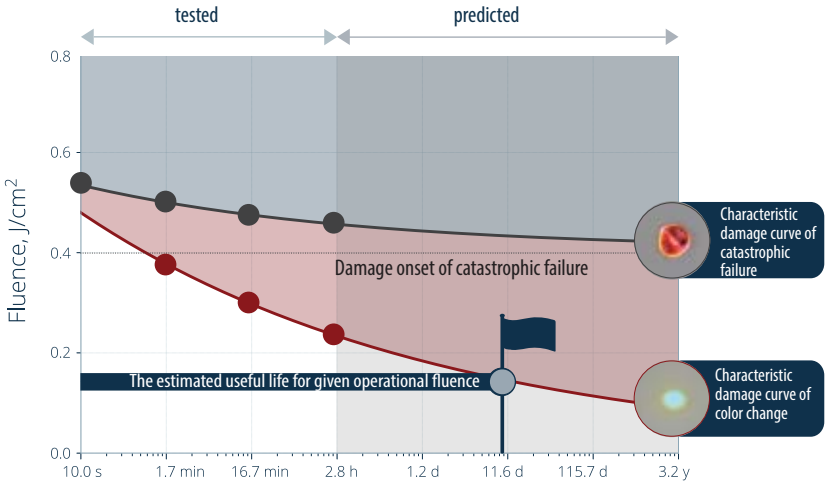


Fig. 3 Graphical visualization of optics' lifetime estimation. Measurements are performed with extended irradiation doses. Failure types are separated and interpreted individually. By applying the Bayesian interference approach, the prognosis of optics behavior is made years into the future. The useful lifetime can then be selected for any operation fluence based on real-life applications. (Source: Lidaris)

lasers, so standard LIDT testing might not be sufficient to address the needs of optics characterization for ultrafast laser applications.

It is a well-known fact that optical elements used within high-power laser systems suffer from a light-induced fatigue effect, namely delayed degradation of optical properties due to repetitive exposure to intense laser irradiation. There are several known fatigue mechanisms. One of them is the so-called statistical fatigue, which can be related to defects embedded in the optical elements during manufacturing processes (cutting, polishing, coating, cleaning, etc.), such as nodular defects, absorbing particles, cracks, porosity, etc. Usually, such defects exposed to intense laser irradiation will result in catastrophic laser damage within tens of applied laser pulses (<100 laser pulses). Catastrophic laser damage consisting of randomly localized dark dots typically appears when irradiated with a large beam. There is no direct correlation between damage morphology and the spatial distribution of the irradiated beam. If an optical element has a high defect density, the statistical fatigue is well characterized by the typical S-on-1 test.

Another type of fatigue is related to material modification due to native and laser-induced states of the material. Material modification fatigue is more likely to start at longer irradiation doses (≥1,000 laser pulses). It is mostly related to late non-catastrophic color change – apparent by differential interference contrast (DIC) microscopy as a smooth dark area nicely replicating the beam intensity pattern on the sample surface. At continuous exposure, the color change can result in catastrophic laser damage in time, so it is equally important and dangerous as catastrophic laser-induced damage. However, typical S-on-1 tests (especially when <1,000 pulses are used) become insensitive to detect this type of failure. It is one of the reasons why even certified or tested optical elements sometimes fail unexpectedly during long-term operations.

Predictions of the optics' future behavior should be made in order to avoid delayed failures of the optical elements used within ultrafast laser systems. This is not an easy task, since the longevity prognosis should be made from measurement-limited and censored data.

To address this problem, Lidaris joined forces with the European Space Agency (ESA). During the ESPRESSO project (Essential preparation steps for qualification longevity of space optics) a new testing concept – the irradiation of optics with millions of laser pulses and predicting their degradation trends at billions of laser pulses – was introduced, demonstrated, and validated in a nanosecond laser pulse regime [1]. The research in this field continued during the joint UNIPULSE project, including Ekspla, Optoman, and Altechna R&D. It was dedicated to creating a universal platform for short-pulse generation. The project successfully adapted the lifetime estimation procedure to the femtosecond pulse regime.

The suggested procedure for optics lifetime estimation is an adaptation of the typical S-on-1 test. In this case, the statistics of damage and survived sites are collected by using extended laser irradiation doses of up to a million laser pulses on each test site or more. Usually, 1,000,000-on-1 LIDT tests are unreasonably time and money-consuming. However, testing with high-repetition femtosecond or picosecond laser sources (up to 1 MHz) is still commercially viable and provides sufficient statistical analysis to make prognosis years into the future. In order to make correct assumptions, it is very important to identify and separate laser damage triggering physical mechanisms – types of failure. According to the ISO 21254 -1 standard, laser damage is defined as any visual modification of the optical surface. However, different failure types show different

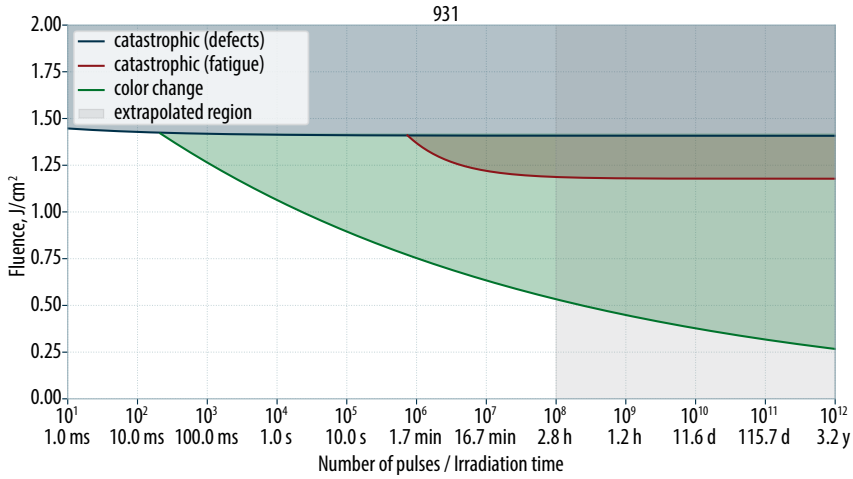


Fig. 4 Lifetime measurement and extrapolation results of sample 931 (Sample source: Optoman, measurement: Lidaris)

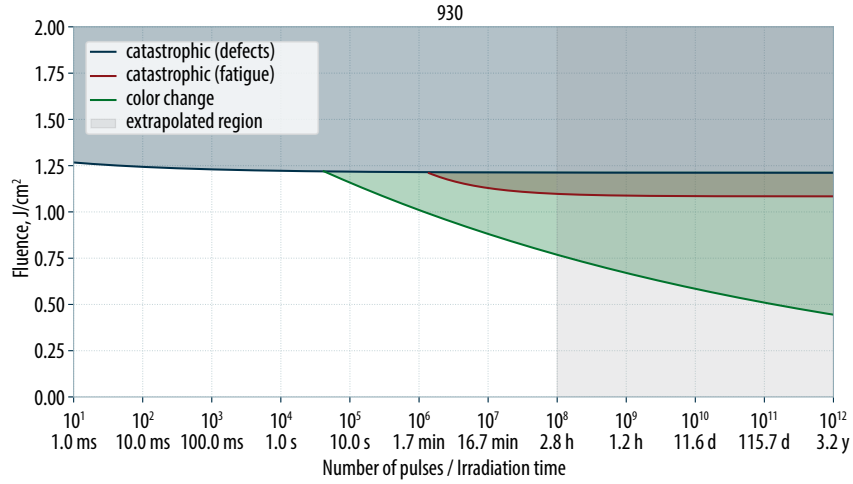


Fig. 5 Lifetime measurement and extrapolation results of sample 930 (Sample source: Optoman, measurement: Lidaris)

	Sample no. 931	Sample no. 930
Catastrophic (defects) LIDT fatigue limit, J/cm²	1.41	1.21
Catastrophic (fatigue) LIDT fatigue limit, J/cm²	1.18	1.08
Color change 10^8-on-1 LIDT, J/cm²	0.51	0.78
Absorption (1,070 nm, Linear S), ppm	2.7	<1
Absorption (1,070 nm, Linear P), ppm	4.9	1.6

Table Comparison of samples 931 and 930 provided by Optoman and measured by Lidaris

long-term trends, so fatigue behavior should be extrapolated for each identified failure type independently. The data extrapolation procedure is based on the Bayesian statistics approach (Bayesian interference) [2]. It is a more accurate and precise method than standard extrapolation techniques as it allows different damage detection techniques to be combined with the correct representation of censored data. By using this procedure, optics lifetime can be predicted up to a few years into the future. The useful lifetime can then be selected for any operation fluence based on real-life applications. Characterization of the optical element is no longer one fixed value (typical LIDT at a fixed number of pulses), but rather a set of information about useful available lifetime that helps to provide guarantees for specific use applications.

Another important factor in optics longevity characterization is absorption. Intense laser irradiation applied to the optical elements may cause strong changes in the refraction index, leading to a loss of their specified performance. The limit of laser power where beam distortions become significant might be regarded as a 'functional' laser-induced damage threshold (or F-LIDT). As accumulated heat is the main reason for functional damage, it is important to characterize absorption losses in thin films to predict the limit of functional damage. Photothermal common-path interferometry (PCI) is probably the most popular option for the characterization of low-loss optical absorptance of dielectric coatings at a ppm level. High sensitivity (up to 0.1 ppm); good temporal and spatial resolution enables advanced testing procedures such as longitudinal scan (L-scan), transverse scan (T-scan), time-scan, and 2D area scans, which reveal much more detail on coating properties than was possible up until now. By using the PCI technique and pulsed irradiation, a direct observation of nonlinear absorptance and how it changes in time also becomes possible, providing even better insight into optics' performance-limiting factors.

As both LIDT and absorptance testing play a critical role in evaluating the durability and reliability of laser optics, Optoman and Lidaris continue to cooperate to assess the performance limits of the optics, ensure the highest quality standards are met and laser optics will withstand the demanding operating conditions of the ultrafast laser.

The LIDT and the lifetime of two different, highly-reflective dielectric mirror samples (sample No. 930 and sample No. 931) were measured. Both mirrors were optimized for the following laser parameters:

- Wavelength: 1030 nm
- Pulse duration (FWHM): 500 fs
- Repetition rate: 10 kHz
- AOI: 45°
- Polarization: Linear S
- Beam diameter ($1/e^2$): 185 µm

Mirrors differ in coating designs, coating parameters, and pre and post-coating procedures. The goal was to find the optimal manufacturing parameters to ensure the long lifetime of mirrors.

The measurement indicates that catastrophic LIDT values are higher for sample no. 931. However, the same sample starts degrading under a shorter irradiation time as the color change effect becomes noticeable after 100 ms. While catastrophic laser damage leads to a crater inside the coating which scatters the light, the color change effect is also important to take into account as it affects the laser pulse shape and temporal characteristics. Eventually, further

degradation leads to catastrophic laser damage. So, it is not enough to have a high catastrophic LIDT, as working with ultrashort pulses of 10 ps and less the color change effect becomes the LIDT limiting factor that shortens the lifetime of optics.

That is why sample no. 930 is much more suitable for ultrafast applications. Even though catastrophic LIDT is 10 – 15 % lower than sample no. 931, the color change effect begins later. And most importantly, the lifetime extrapolation predicts real-life application requirements and demonstrates that sample no. 930 after 3.2 years of irradiation time has almost 2× higher LIDT values than sample no. 931 (0.48 J/cm^2 over 0.26 J/cm^2). Market standard LIDT values for equivalent products are between 0.4 – 0.7 J/cm^2, but in most cases measured for a number of pulses of up to 10^5, while the samples presented here were measured for 10^8 laser pulses and extrapolated up to 10^{12}.

The most important parameter that ensures a long lifetime of optics is the absorption value. Sample no. 930 has an absorption value several times lower than sample no. 931, which was measured using low-loss absorption (PCI) longitudinal, temporal, and transverse scans. Low absorption coatings are achieved by employing ion beam sputtering coating technology together with the know-how of the appropriate choice of coating materials, coating parameters, and specific pre and post-coating processes, the combination of the right infrastructure and highly experienced staff.

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[2] *L. Smalakys* et al.: Opt. Express, **29**, (2021) 2, 903

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Full article online and in PhotonicsViews issue 3/2023

Where flexibility meets precision

Recent advancements of the industrial femtosecond laser

The development of ultrafast lasers with higher functionality as a result of recent advances in the study of light-matter interaction has revolutionized the micromachining of materials with greater accuracy and a smaller heat-affected zone. The popularity of femtosecond lasers in industry has furthered enhancements to their flexibility and efficiency, including different methods of operation such as in the FemtoLux 30, enabling new techniques in material processing.

FemtoLux 30 femtosecond laser system with Harmonics unit.

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The future of dicing is here

High-precision processing of transparent materials for various applications

Modestas Vainoris, Ernestas Nacius, Paulius Šlevas, and Vytautas Sabonis

Source all images: WOP | Workshop of Photonics

The submicron era is here, and the projections show that the need will only increase for wafers, glass, ceramics, and metal parts with micron and sub-micron-level features on them. Such parts could be readily assembled into multi-layered chips or devices, but still require some dicing. The highly flexible FemtoGlass system with Workshop of Photonics' (WOP) patented cutting technology [1] offers highly efficient and precise dicing solutions with a small heat-affected zone (HAZ) and low surface roughness.

Company

Workshop of Photonics | WOP

is one of the leading femtosecond laser micromachining solutions providers for industry and science customers around the globe.
WOP delivers fully integrated services from feasibility and prototyping to actual solutions – micromachining services and tailor-made laser workstations. WOP laser solutions are based on over 19 years of expertise with exceptional know-how in glass micromachining, using groundbreaking technologies and delivering top precision results.

www.wophotonics.com

Meet us at the Compamed, Hall 8B, Booth L37

There are few different methods to dice materials – saw dicing, stealth dicing, laser dicing, laser scribing coupled with saw dicing, and plasma dicing [2]. All the methods have their strengths and drawbacks, such as HAZ, chipping, debris, and added stress to the cut part. Therefore it is crucial to choose the most suitable technique for your industrial needs. Reliability, flexibility, stability, and repeatability all play an essential role in choosing the right tool for your needs.

Even though saw dicing is a relatively low-cost and low-footprint method, it's not 'cutting it' anymore. Saw dicing introduces a lot of mechanical stress, the diced parts require post-processing and, most importantly, there are limits introduced by the street width.

The combination of laser and saw dicing alleviates some of the problems, but the street width and debris still remain to limit its applicability. Another big drawback is that it requires transportation between the two processing tables.

Stealth laser dicing has lower surface chipping and narrower street requirements. Even though it has one of the fastest dicing rates, it is very limited by the material it cuts and the shapes it can produce (Table 1).

Fig. 1 FemtoGlass, a glass and sapphire laser dicing system developed by WOP | Workshop of Photonics

Using only laser dicing with ultrashort pulses (femtosecond pulses) has significant advantages over other dicing methods. The dicing method using a femtosecond laser offers superior processing – it is not limited by crystalline or amorphous materials, nor by the thickness of the material, has low HAZ, and leaves no chipping or residue on the surface.

Perfect glass cuts

Glass is widely used in many industries because of its excellent physical properties (non-conductive, hard, transparent, chemically inert). Glass can be easily applied and is therefore widely used in consumer electronics and microelectronics, the automotive industry, microfluidics, photovoltaic devices, and various microelectromechanical systems (MEMS).

Glass substrates also have a tailorable coefficient of thermal expansion (CTE). It is achieved by changing the additives and their amount in the glass composition.

As there are many different possible applications, there are also many different types of glass that have diverse chemical compositions, starting from pure fused silica and ending with various tempered or untempered glass types. Besides the many types of glass, they also come in different thicknesses and sizes. The thickness of the glass can vary from ten microns to centimeters, and might be meters in width.

With such a wide field of applications and many different properties, the dicing of glass and even already manufactured products requires a flexible, robust, and accurate dicing method. It is critical to dice with no chipping, have excellent mechanical strength, and a low diced edge surface roughness. All-in-all, our FemtoGlass system can perfectly cut all kinds of glass with ease (Fig. 2).

As can be seen from SEM images, even round and angled features on the parts cause no problems in achieving an even cut with low surface roughness ($R_a < 1$ µm). When using a femtosecond laser system, the parts have no offcuts or chipping. Such cuts allow the parts to keep high mechanical strength, and the quality of the cut is not dependent on the thickness of the sample.

Saphire cutting

Various semiconductors having wide bandgaps are also widely used in light emitters, diverse MEMS, and high-powered electronics. Such ceramics – SiC, sapphire, GaN, etc. – are also used under adverse conditions – high temperature, high friction, radiation, etc. – where common Si-based electronics become nonfunctional.

	Saw	Stealth laser	Laser ablation	WOP FemtoGlass
Glass thickness	2 – 19 mm	200 µm – 10 mm	30 µm – 2 mm	30 µm – 10 mm
Glass type	All types	Non-tempered Sapphire	All types	Tempered Non-tempered Sapphire
Cutting speed	up to 100 mm/s	Up to 300 mm/s	Up to 10 mm/s	Up to 800 mm/s
Possible shapes	Straight cuts only	T-shapes and circular shapes are possible	Any shape	Any shape possible
Surface chipping	<200 µm	<50 µm	<50 µm	<10 µm
Street requirement	>50 µm	<15 µm	>50 µm	<1 µm
Water (cooling / cleaning)	yes	no	yes	no
Debris	yes	no	yes	no
Thermal effect on device	yes	no	yes	no

Table 1 Comparison of different dicing techniques

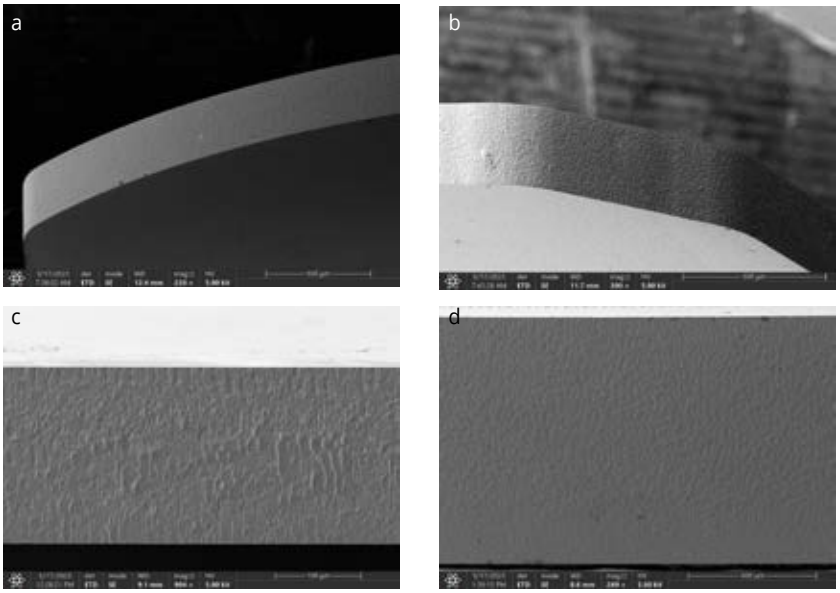

Fig. 2 SEM images of D263T glass (a, b) of 300 µm thickness, and fused silica, (c) t = 250 µm, (d) t = 1 mm diced using the FemtoGlass system.

Such ceramics or their coatings are extremely hard and usually very brittle. All of them are crystalline materials that have a regular structure. Because of the crystalographic planes, which could allow the crystalline planes crossing the surface of the ceramics, cuts along some of these crystalline axes make dicing along these axes much easier.

However a part made from ceramics or other pure crystalline materials would rarely have no rounded edges or irregular shapes. Such brittle ceramics have usually been diced using blades or wires [3], although these methods introduce a lot of chipping and require post-dicing cleaning.

Saphire is notorious for being a complex material to dice cleanly [4]. At the same time, sapphire is a desireable material because of its chemical stability and ultrahigh hardness. It is often used as a cover glass for phones or tablets. Also, many devices are grown on sapphire substrates, especially LEDs made with InGaN/GaN. Such applications require high-quality reflecting faces with minimal chipping and high edge strength.

SEM images (Fig. 3) demonstrate that this system can handle quite thick sapphire wafers, and the edges are chip-free. The overall cut is ultrasmooth, and the optical profilometer data (Fig. 4) shows that the surface roughness does not exceed 0.5 µm. These cuts have superb repeatability and, as seen from the SEM images, can be diced into almost any shape.

Conclusions

The use of femtosecond lasers has caused a revolution in material processing. The flexibility, accuracy, and efficiency of the FemtoGlass laser system allow us to apply it in almost any industrial field where dicing is required.

The capability to dice all sorts of glass and other crystalline materials up to 10 mm in thickness, with high processing rates (up to 800 mm/s), and the cleanliness of the process show unmatched potential for use in a wide range of micromachining applications.

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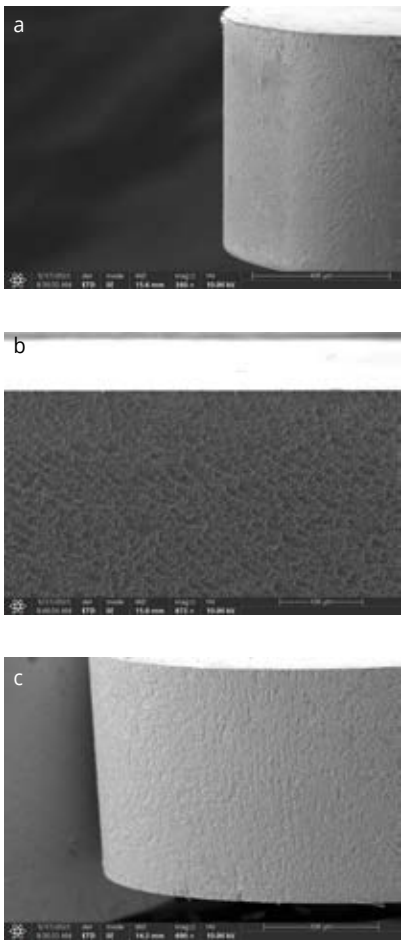

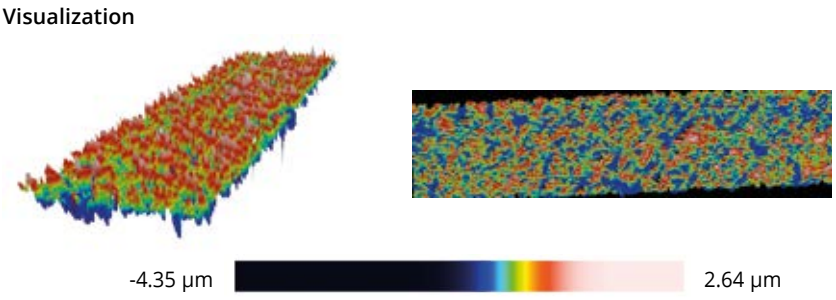

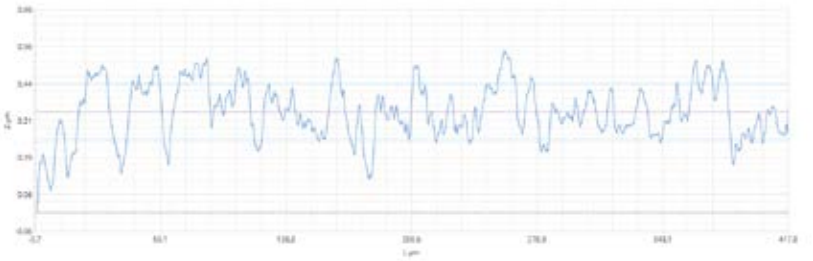

ISO 25178 / Height

Sa	0.3424 µm	Sq	0.4413 µm
Sku	3.8852	Ssk	0.0230
Smean	-4.4 e-12 µm	Sv	4.3520 µm
Sp	2.6371 µm	Sz	6.9891 µm

◀ **Fig. 3** Saphire parts diced using a FemtoGlass system: (a, b) *t* = 700 µm, (c) *t* = 350 µm

▲ **Fig. 4** Optical profilometer data of the round part of the diced sapphire using the FemtoGlass system

[1] WOP patent: see WO 2020230064A1

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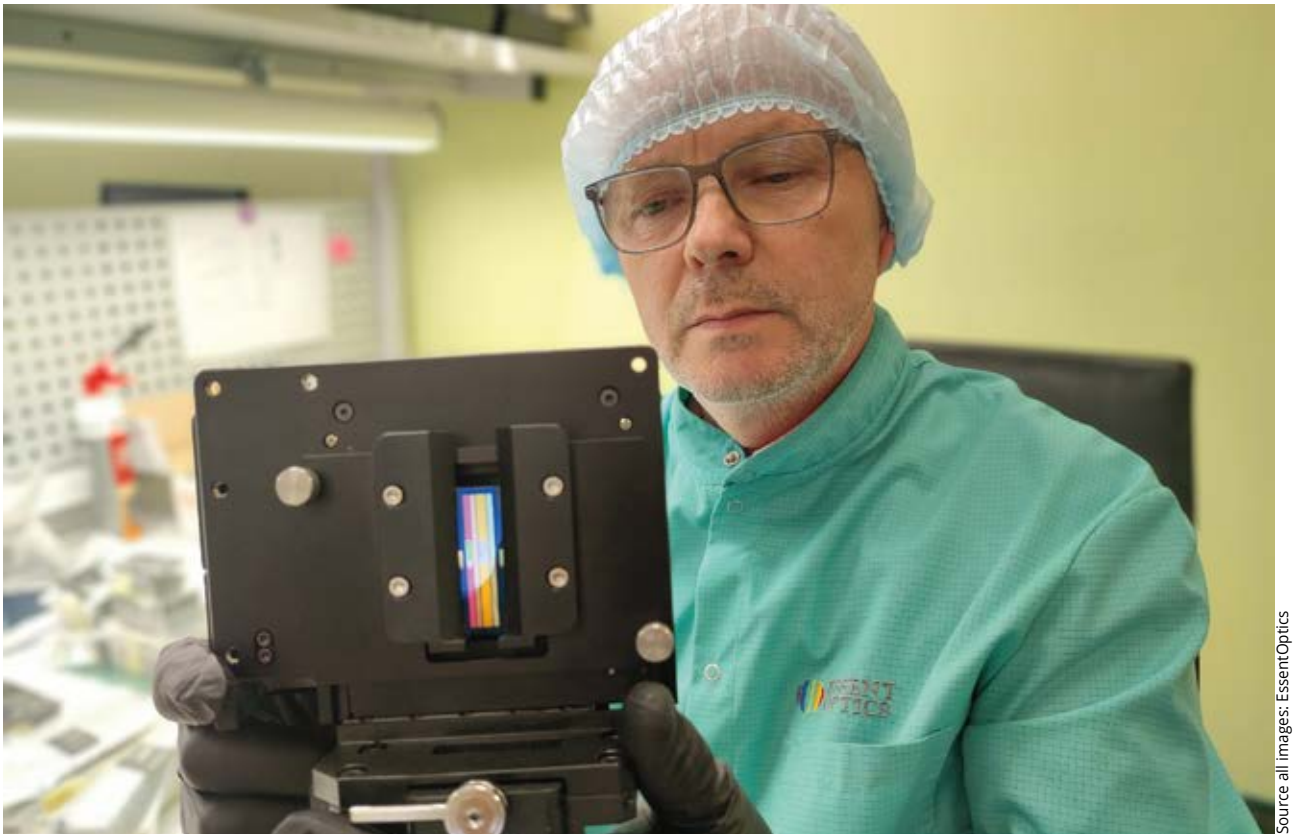
The traditional approach is no longer sufficient

A new method of broadband spectral measurement of optical coatings

Taras Lisouski



Source all images: EssentOptics

Optical coatings play an enormous role both in our daily life and in advanced research. Virtually any optical element – from a simple lens to the ones used in the sophisticated laser systems, space instruments or data transmission cabinets – have optical coatings. New designs of the coatings and new applications require an upgraded and often designed-from-scratch technology to meet the continuously growing thin film optical metrology specifications.

Modern optical coatings are designed to operate within a very broad wavelength range from UV to IR, are applied on different sizes and shapes of the substrate, and often contain tens or hundreds of thin film layers.

Analytical spectrophotometers have been used for spectral measurements of optical coatings for decades. Without almost no exceptions, users purchased basic units and later had to order multiple inconvenient and costly fixtures or accessories in order to 'adapt' the chemistry-focused spectrophotometer to the needs of optical coaters. Each accessory added its own degree of error to the final measurement results. Exchanging the fixtures was time-consuming and still did not serve the needs in full. At the same time, modern coating departments often operate 24/7 and require quality inspection for the most or all of the coatings produced. Insufficient adaptation of traditional spectrophotometers to new metrology challenges have led to an expected effect – manufacturability of the optical coatings has surpassed traditional metrology solutions used for their quality inspection. The coating companies have rapidly gained expertise and technology to produce sophisticated coatings but faced ever more restricted capabilities to qualify them.

▲ EssentOptics engineer holding the XY-MZF stage with a multizone filter placed on it right before measurement.

At EssentOptics, we have faced the same challenges since our engineers have had past experience in the production of optical coatings. There was a clear

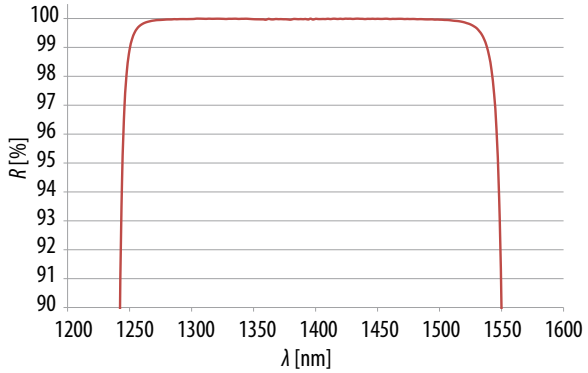


Fig. 1 Measured results of a high-reflection interference mirror containing 30+ layers. The best absolute reflection value achieved is 99.995 %. No values exceed 100 %.

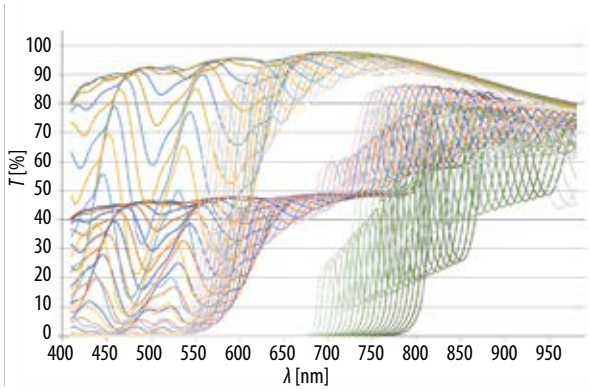


Fig. 2 Unattended transmission measurement of the 1" polarizing cube, the angle of incidence is changing from 0° to 20° in 1° steps. Detector position is adjusted automatically to the refracted beam.

necessity to design a spectral measurement instrument tailored to the needs of coaters. A number of design and usability prerequisites were imposed by a development team that was formed to devise the new technology.

As a cornerstone, it was determined that each and every element/feature of the instrument shall be critically analyzed and tailored to meet thin film optical metrology needs.

Time-consuming routine and multi-level group measurements shall be automated, including elimination of most of the manual operations (like alignment procedures or adding / replacement of the optical elements during measurement).

One of the key disadvantages of the traditional approach was seen in the presence of the various, often inconvenient, reflectance attachments with must-use reference samples, leading to measurements of not absolute but only relative specular reflection values. The new design approach underlined the necessity to ensure absolute reflectance measurements by default.

Broadband measurement capability was another critical need meeting the growing capability of coaters to produce a wide range of sophisticated coatings.

Low noise measurements with good repeatability were also added to the 'wish list'.

Changeovers – characteristic areas on the graph where the signal changes abruptly due to the change of grating or detectors – shall be eliminated or reduced to values below 0.2 % (compared to units of a percent typical to other instruments).

Finally, the extensive and permanent communication with coaters was put at the forefront of the whole design process.

The combination of these requirements and approaches formed the solid development basis for a family of the state-of-the-art Photon RT and Linza spectrophotometers for optical experts.

Different types of components require different measurement approaches

In general, all of the optical components can be divided into two clear groups – flats and lenses. Whenever we consider plano optics like filters, mirrors, polarizers, beam splitter cubes and even complex cemented prisms, in all cases we are dealing with finely-polished plane parallel surfaces with a multilayer stack that has been vacuum deposited on one or more faces. In the majority of the cases, these coatings operate at normal or clearly defined ranges of angles of incidence and in polarization-dependent environments. The family of Photon RT spectrophotometers from EssentOptics serves this very need. Two instrument platforms cover seven configurations (models) relative to the wavelength range, from UV to LWIR. The shortest one is 380 – 1,700 nm, the most knowledge-intensive configuration offers a world-record 185 – 5,200 nm measurement capability. Unsurpassed until now, this record was set in 2019. A separate model, Photon RT 7512 was built on an individual platform to offer LWIR measurement capability (7,500 – 12,500 nm).

The cases below describe new solutions developed for effective elimination of the challenges faced by coating companies.

Case 1: High reflection interference mirror

High reflection interference mirror coatings are produced with alternating layers of high-index and low-index materials and widely used in laser systems. Reflection often reaches values well beyond 99 %, even 99.99 %. Low noise measurements are critical to qualify these coatings. Optical experts also expect to see measurement spectra without outliers (see Fig. 1) which are often present with traditional spectrophotometers.

Case 2: Beam splitter cubes

Polarizing or beam splitter cubes comprise two cemented right-angle prisms, with highly sophisticated polarization-dependent or specular-dependent coatings isolated on the hypotenuse. In addition, antireflective coatings are applied on most or all of the front surfaces. During the thin film design simulations, the beam enters the cube and is split in two, each of them separating S and P polarizations. The Photon RT spectrophotometer has a built-in capability to perform cube measurements

Company

EssentOptics Europe

EssentOptics design and build spectral measurement systems used exclusively for transmission and reflection measurements of optical coatings on flats and lenses. The company was founded in 2009, and since then it provides high-end, tailored inspection solutions for the optical coating industry.

www.essentoptics.com

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and simulate its performance virtually, in the same way as it was designed and calculated. The baseline is calibrated upfront for S and P polarization states of light using the built-in high contrast broadband polarizers placed on the optically-aligned motorized drive. Next, the cube is placed on the stage and, initially, is kept immovable. The detector head with up to three high-sensitivity detectors can freely rotate clockwise and counterclockwise, ensuring polarization dependent measurements for all transmitted beams. Unlike most of the 'chemistry-type' spectrophotometers that usually have a beam divergence of ±5 degrees, the arrow-like beam generated by the monochromator inside the Photon RT instrument has a ±1 degree cone by default. The presence of the highly collimated beam ensures that the polarization properties of the coatings are measured exactly at pre-set angles and with very high accuracy.

The Photon RT also has a precise drive mechanism placed under the detector head that scans the detectors sideways, providing 'eagle-eye' signal capturing capability to measure a parallel-shifted beam due to its refraction inside the optical sample. Simultaneous operation of various drives ensures the rotation/scanning of both the detector head and the sample stage, providing unattended angular and polarization-dependent measurements of the cubes or cemented prisms with arbitrary arrangement of outgoing beams (see Fig. 2). The capability to measure transmission of thick samples at high angles of incidence is required for qualifying complex cemented prisms used in modern projection systems and advanced hyperspectral imaging systems. Currently this technology is commercially provided as standard only with Photon RT spectrophotometers.

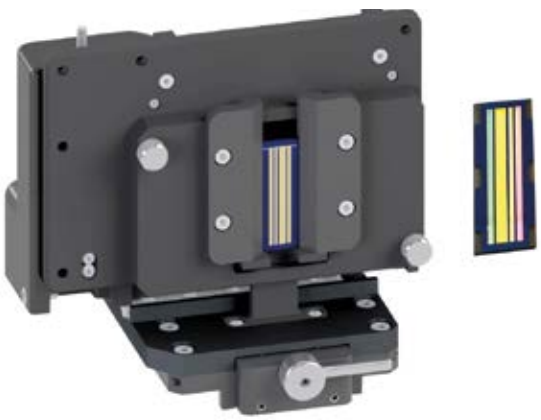

Fig. 4 XY-MZF motorized stage designed for transmission measurement of multizone filters and linear variable filters.

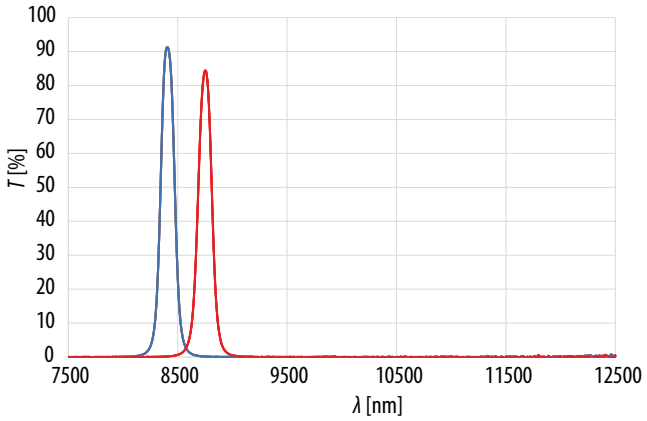

Fig. 3 Measured results of long-wave infrared, narrow bandpass filters. Noise level does not exceed 0.2 % for most of the range.

Case 3: Optical coatings for long-wave infrared range

Optical coatings for mid-wave infrared and especially long-wave infrared applications were historically measured with bulky dispersive spectral instruments. Wide adoption of a cheaper FT-IR technology has offered much faster measurement capability and later become a widely accepted replacement for the dispersive spectrophotometers. However, it has turned out that the new technology serves very well for biology and chemistry but still lacks critical factors needed for the optical coating community, like a low noise level, measurement accuracy and repeatability. The latest Photon RT 7512 model from EssentOptics was designed and built as a classical dispersive spectrophotometer, but re-invented in almost every engineering aspect. The focus was on the challenges not found in UV-VIS-NIR dispersive instruments – a reliable broadband light source, effective management of the dynamically changing background radiation, fast measurements, the capability to measure low level signals both with and without polarization states of the IR radiation. For almost two years, a team of engineers with deep backgrounds in optics, mechanics, electronics and software evaluated different concepts and tested components as potential candidates. The resulting instrument represents a combination of interrelated solutions and approaches, all bringing a synergetic effect. Key design innovations and configuration included the IR light source with 5,000 hours service life and high illumination stability, an original optical scheme with a new monochromator, new beam spot control technology, a low-noise / deeply cooled IR detector, and newly implemented beam management technology serving to reduce the influence of background. Measurement tests of the IR narrow bandpass filters demonstrated a smooth spectrum with substantially lower noise compared to traditional measurement technologies, just below 0.2 % within almost the entire range (Fig. 3). The new instrument also inherits the beam displacement feature, albeit significantly redesigned. The presence of this measurement capability is critical: some of the front windows used in defense-related optical instruments are made of germanium, have up to 40 mm thickness and face signals coming from various directions. Given the high refractive index of such a substrate, the beam offset can reach extreme values.

Case 4: Multizone filters

The rapid growth and availability of earth observation and remote sensing technologies has given rise to a growing number of companies offering advanced, tailored thin-film optical coatings for these applications. Such coatings usually separate different zones from ultraviolet to short-wave infrared spectral regions. Multilayer thin film stacks are deposited to select channels (bands) and spatially distribute them on the substrate. Final products are always customized for overall size and spectral performance, as well as for the number, size, and location of bands to address various customer needs. Verification of the spectral performance of the finished multizone filters represents a true metrology challenge. Individual zones can have a width of less than 1,000 microns, so a very narrow beam spot must be used to attest such a band. The layout of zones

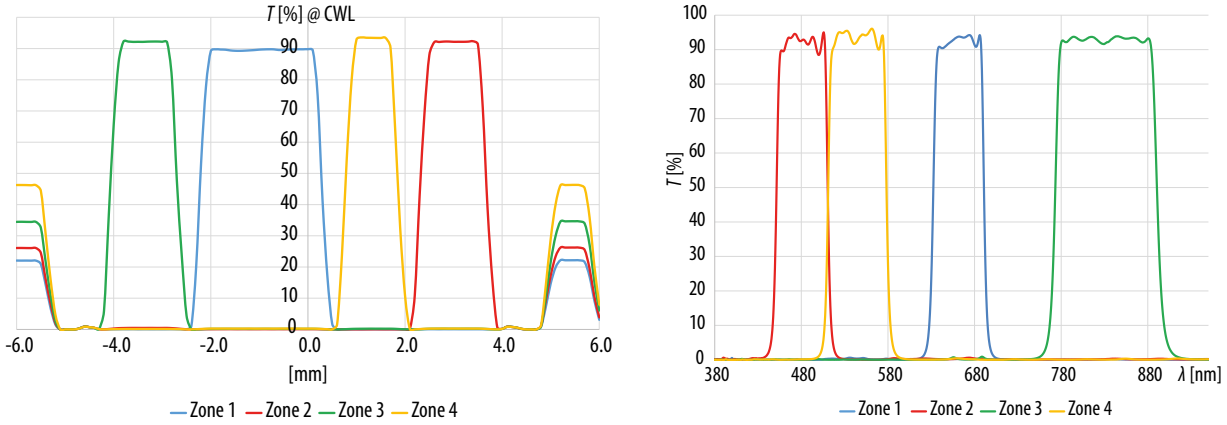

Fig. 5 & 6 Zone detection and zone measurement of the multizone filter. The Zone 4 (yellow lines) has a physical width of the band of just 700 µm.

is customer-specific. The filter size can also vary depending on the mating array. Some of them need to pass quality control not just in the center of each zone, but also close to the filter edges. The typical measurement of multizone filters is accompanied by significant losses of time, numerous manual manipulations, and potentially inaccurate measurements. EssentOptics has developed the XY-MZF motorized stage for Photon RT spectrophotometers (Fig. 4), focusing specifically on fast, unattended, and high-quality spectral measurements of multizone filters, as well as linear variable filters (both continuously variable and step variable filters).

The stage can house substrates with a size up to 50 mm × 40 mm. The width of an individual filter zone can be as small as 700 microns. The number of zones for each filter is not limited. Computer-controlled XY mapping helps to measure virtually any part of the individual zone. Zone detection (Fig. 5) and zone measurement (Fig. 6) are both performed unattended, without extracting the sample or the stage from the instrument.

Spectral measurement of lenses

Spectral measurement of lenses has traditionally attracted less effort and attention due to a very simple fact – transmission or reflection of the lens is usually examined with a flat witness sample placed in the center of the calotte or in close proximity to the deposited lens itself on the dome-type or planetary fixture inside the vacuum chamber. The use of witness samples is inevitable as there is no possibility to measure the actual transmittance or reflectance of lenses during the deposition process. However, optical coating on lenses is often not the same as on the witness sample – the thickness of individual layers differs along the lens surface due to the lens curvature.

A reliable technology for spectral measurement of lenses brings a valuable benefit. From the end-user standpoint, the information about actual transmittance or reflectance of the real lens is critical for many applications since lenses serve as a first optical element facing the incoming radiation in the absolute majority of applications. Most of the imaging systems utilize more than one lens, so the spectral performance of the complete lens objective has to be inspected as well. On the other hand, having meaningful data about the distribution of transmission/reflection (or thickness uniformity) of lenses placed over the entire surface of the calotte in the vacuum chamber would help the coating companies to manage the deposition process in a more efficient way. The coating engineer can perform backward analyses and adjust key process parameters like the deposition rate, the rotation speed of the fixture, mask positioning and mask shape, and select better placement for lenses to attain better uniformity. Altogether, this would lead to higher process yields and reduced costs.

The measurement of lenses is associated with challenges different from those typical for transmission and reflection tests of flats. Convex, concave, spherical, aspheric and cylindrical lenses have diameters of less than one millimeter to hundreds of centimeters. The inspection process should not damage the lens. Convergence or divergence of the beam propagating through the lens impose further critical challenges as these directly influences the amount of the useful radiation entering the detector of the spectrophotometer.

The introduction of the EssentOptics Linza 150 system in 2018 has opened a completely new chapter in the unattended, high-quality transmission and reflection measurement of lenses. The new system, the first of its kind on the market, covers the 185 – 1,700 nm wavelength range and solves three main measurement needs – on-axis transmission of lenses, on-axis transmission of lens assemblies (objectives), and reflection

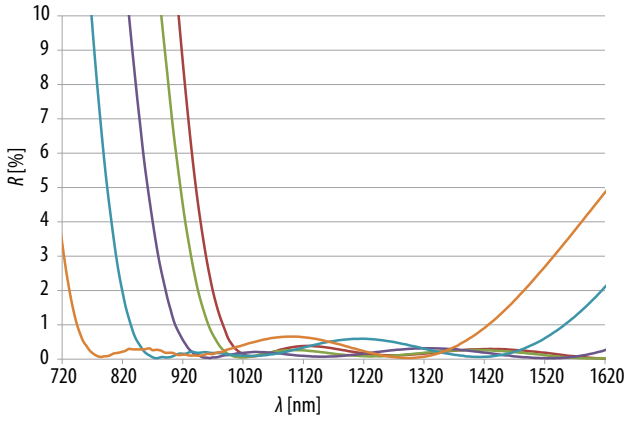

Fig. 7 Fully automated reflection measurement of the convex lens, on-axis and at 5 mm steps from the lens center out to the edge.

of lenses both on-axis and at any point of the lens surface. All types of coated lenses described above can be successfully measured with the Linza 150 system. The built-in reflection measurement capability is achieved by using a three-axis robot mechanism placed inside the instrument and controlled by the computer. Once the baseline calibration is completed, the engineer just needs to place and fix the lens in the self-centering lens mount. Next, basic lens design data like diameter, radius, convex/concave/aspheric shape and chamfers have to be selected in the parameters window. Three robot drives position the lens against the focused beam spot to place it exactly on the lens surface.

The Linza 150 system is irreplaceable when it comes to deep analyses of the coating on the real lens, and, additionally, the performance of the deposition process. Fig. 7 shows an example of the AR-coated convex lens (diameter 43.0 mm, radius 28.0 mm). Near infrared reflectance was measured at the lens center and in 5 mm steps to the lens edge in a fully automatic mode. The non-uniformity is estimated at 20 %, this data provides plenty of opportunities for subsequent analyses and improvement of the deposition process, including the use of a planetary fixture, masks etc. The lack of such data or using a traditional quality control procedure with a witness sample leads to potentially lower overall performance of the optical system where such lenses are used.

Conclusion

The Photon RT and Linza families of automated spectrophotometers cover a wide range of wavelengths from 185 up to 12,500 nanometers, and offer fast and meaningful results both for routine and the most demanding thin film metrology needs.

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Taras Lisouski is one of the founders of EssentOptics Europe. He supervises business development and motivates his colleagues to set new frontiers in high quality spectral measurements of optical coatings.

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The best of two worlds

3D laser manufacturing of custom components in the micrometer and submicrometer range

Founded in 2013, Femtika is a spinoff company of the Laser Research Center of Vilnius University, Lithuania. The experts there have many years of experience in the research and development of 3D laser precision micromachining, and they specialize in hybrid micromachining technology.

Femtika has been using Aerotech's linear stages and galvo scanners since the company's foundation in 2013 to produce universal tools with femtosecond lasers suitable for multiphoton polymerization, laser ablation and selective laser etching technologies. The heart of a laser nanofactory workstation always consists of a femtosecond laser in combination with a nanopositioning system from Aerotech. These enable fast and highly precise 3D manufacturing across the entire workspace. However, the first contacts occurred much earlier as the University of Vilnius had been using Aerotech equipment since 2005. Femtika's founders used Aerotech equipment intensively for research projects and other academic work.

The experts at Femtika have many years of experience in 3D laser precision micromachining R&D. (Source: Femtika)

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Unravelling the mystery of rising methane emissions

Laser absorption spectroscopy can pull our climate back from the brink

As a powerful tool for detecting trace gases, laser absorption spectroscopy has been widely used to monitor atmospheric greenhouse gases, pollution, and respiration processes, and also for human breath analysis. The detection is based on the light absorption when it propagates through a medium, and as interest in air quality has dramatically increased in recent years, both well-established and new sensor manufacturers are looking for high-performance filters at competitive prices.

To detect the level of light absorption through a medium, emitters within a sensor generate pulses of IR light, passing through a sampling chamber containing a filter. Different filters allow different wavelengths of light to reach the detector, which can in turn be used to detect specific gases and distinct particles that may be present.

Controlling and limiting the reflective properties of filter lenses is crucial to sensor performance. (Source: Umicore)

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https://doi.org/10.1002/phvs.202300028

Thermal management as a process guarantor

Why precise temperature control in laser procedures is decisive for safety and the quality of results

Although effective thermal management is essential for temperature-intensive laser applications, it is far more than a necessary evil, because it makes a decisive contribution to safety, the quality of results and reproducibility. In view of innovative (further) developments in the laser sector, the importance of precise temperature control is growing. Users are demanding highly flexible cooling systems in the form of customized solutions, maximum precision and high reliability.

In recent years, the laser industry has experienced strong growth, driven by the increasing demand from various industries for precise material processing and advanced technology. Perhaps one of the most exciting trends is the increasing use of solid-state lasers in industry, especially fiber lasers, which have successively replaced CO_2 lasers in different fields of application. CO_2 lasers are more powerful due to their higher wavelength and are often better suited to processing non-metallic materials such as wood, acrylic, paper, plastics, leather and textiles. However, in direct comparison, they require more space and cause higher acquisition and operating costs. Fiber lasers, on the other hand, are more compact and economical. They are also becoming increasingly powerful and can now cut, melt or engrave even stronger metals, quickly and precisely.

Source: Technotrans

The piko active cooling system is ideal for applications requiring very accurate temperature stability. The slide-in piko cooler can be integrated into various systems.

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In search of the perfect process

Laser welding of electric vehicle battery cases

High mechanical demands are placed on battery cases as the heart of modern electric vehicles. On behalf of major car manufacturers, WMG at the University of Warwick in the UK tested welding processes for optimizing aluminum battery housings using lasers. In extensive laboratory tests, the ALO4-O processing optics from Scansonic – designed specifically for use on battery cases – were convincing in several respects as it combines the tactile seam tracking of the ALO product family with the laser beam oscillation of a remote optic. The WMG team was able to achieve significant improvements in three important parameters of the process compared to tactile welding without oscillation: improved joint strength by up to 70 %, reduction of heat input by 50 %, and guaranteed gap bridging of up to 45 % of the top material thickness with beam oscillation.

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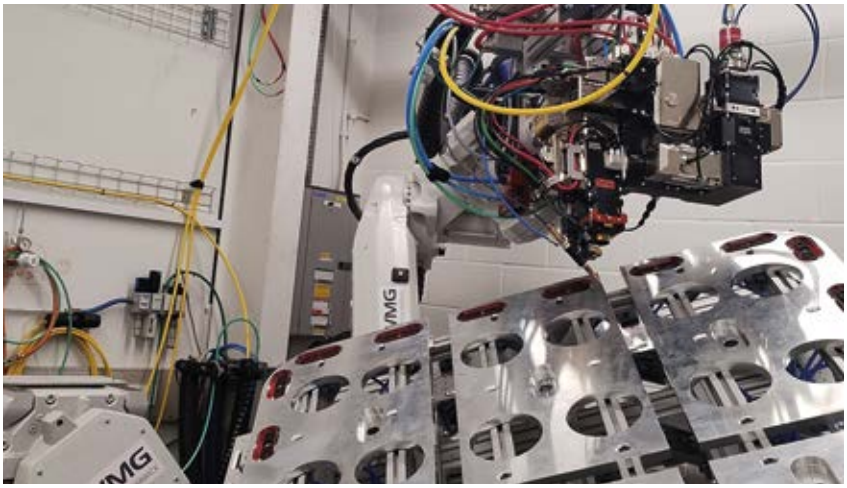

WMG at the University of Warwick have developed an innovative and production-ready method to laser weld aluminum battery cases. The WMG-Team selected the ALO4-O processing optic from Scansonic for the purpose. (Source: WMG, U Warwick)

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The next generation of tactile laser processing heads

Make laser joining easier, established processes more efficient and to enable new applications

For more than twenty years, tactile laser processing has been the state of the art for laser brazing and filler wire-assisted laser welding. The expectations of process efficiency, uptime and machine integration have been growing during this time. A new generation of processing heads is responding to that with a simplified optomechanical design and a monitoring system that continuously shows the status of all critical components. Laser joining has become the method of choice in automotive laser manufacturing. First it was applied at the body-in-white, now it has come to battery welding too. Laser brazing, for example, has been used for roof joints on the outer skin of the car where superior weld quality leads to high stiffness and good cosmetical seam appearance. Most often, such processes are accomplished with tactile laser processing, where the filler wire is used to guide the laser focus along the seam contour.

Tactile laser heads are used in the automotive industry for their excellent weld seam quality. (Source: PT Photonics Tools)

The technology of the new laser processing head MPH-T especially addresses the requirements of the automotive manufacturing industry:

- A simplified optomechanical design requiring less product variants while still fulfilling all application requirements makes the process simulation easier and allows to reduce the spares holding
- The revolutionary and simple (on-site) service and maintenance concept even down to the level of optical modules is a major building block in increasing the uptime of the laser installation
- The unique monitoring and the status visualization of all critical components in the laser processing head including all optical elements indicates to the user always the health status of the optical systems and allows now for a preventative maintenance.

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New intelliSCAN IV series – compact high-performance scan heads

The intelliSCAN IV series is 'ready for SCANmotionControl' (Source all images: Scanlab)

The scan heads of the new intelliSCAN IV series set standards in terms of compactness, performance, and integration capability. Thanks to reduced dimensions and integrated water cooling, they provide greater stability and an impressive twenty percent increase in dynamics compared to previous models.

Powerful and compact scan heads, available with different galvanometer scanner technologies

The new scan head generation is compatible with all RTC drive boards from Scanlab. Users can choose between classic scanner control with a tracking error or the SCANahead control known from the excelliSCAN series to exploit the full dynamic potential of the scan head. The intelliSCAN IV is also 'ready for SCANmotionControl'. The new software enables unprecedented process control while minimizing processing times.

Reference: *Jan Wagner & Holger Schlüter*: Micromachining gains from simulation – Innovative scanning control software reduces development times and time-to-market, PhotonicsViews **20 (2023)**3, June/July 2023; DOI: 10.1002/phvs.202300021

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High-performance welding for safety-relevant applications

Deposition welding with reproducible, predictable quality for safety-relevant applications

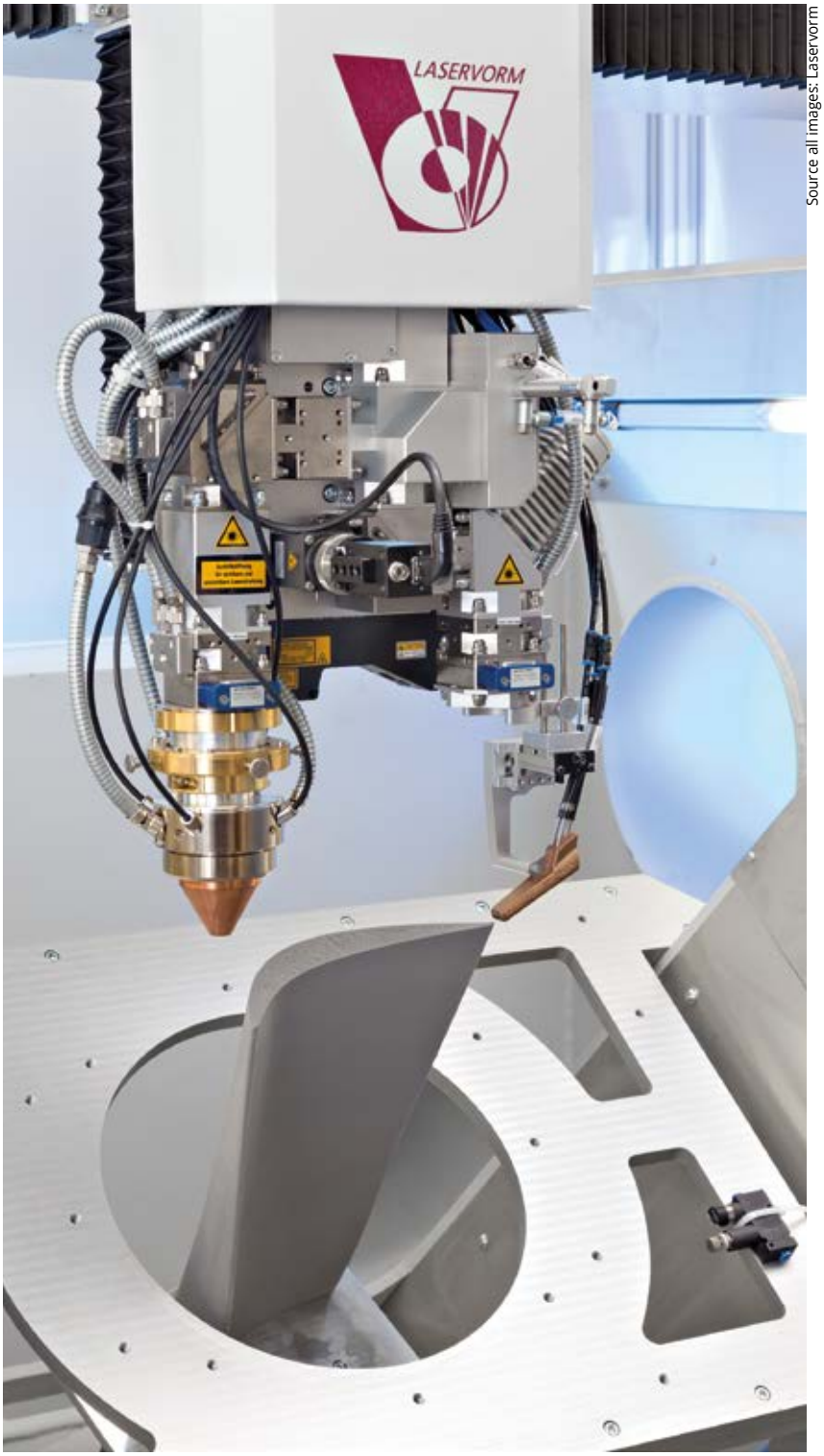
Laser deposition welding helps to speed up the repair process and reduces costs. An important component for this is the new tracing technology from Laservorm, which records at exactly which point of the component which parameters have had what effect.

Turbines are among the most powerful machines: they operate as gas turbines in engines, as steam and hydroelectric turbines in power generation, or in aircraft engines. Gas turbines have an output of up to 600 MW mech, in contrast to steam turbines generating almost 1.8 gigawatts in the largest nuclear power plants, such as the Olkiluoto nuclear power plant in Finland. Several individual steam turbines often operate here at high output in parallel. Hydroelectric turbines can reach over 700 MW, and jet engines in aircraft create up to 510 kN of thrust power.

The blades rotating in the turbines are subjected to enormous forces and are correspondingly susceptible to wear. In order to operate efficiently, turbine blades must be optimally shaped to ensure the best flow and are therefore built to very strict manufacturing tolerances. Even the smallest deviation from the optimum shape will reduce power or engine performance and increase fuel consumption.

Wear damage to aircraft turbines is caused by vibration, friction, or erosion due to sand and dust particles, hard landings or when birds are drawn into the engine. Each type of damage is different and has to be repaired appropriately. The process therefore requires accurate recording of the process data and its analysis.

A single new turbine blade can cost several thousand euros, depending on its stage within the compressor and the engine size. Repairing a blade costs significantly less than purchasing a new



Source all images: Laservorm

Fig.1 Tracing of the parameters is important for safety-relevant applications like turbine blade repair to control the cladding process.

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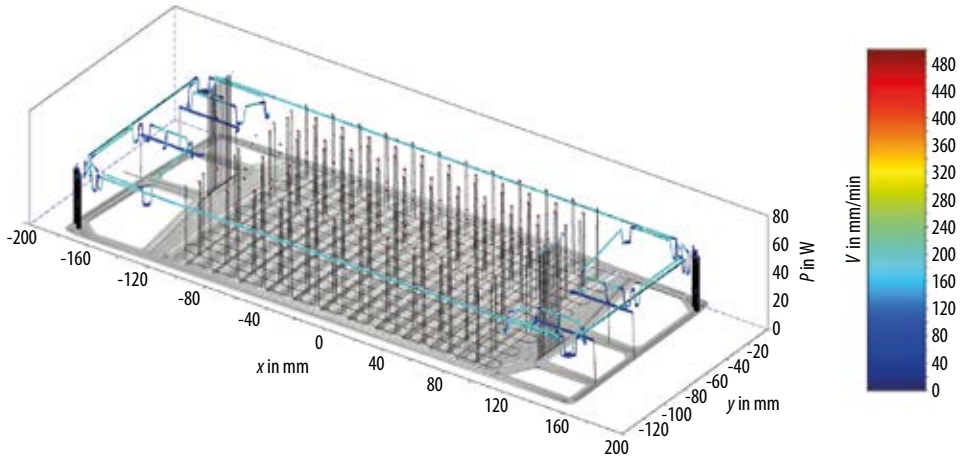

Fig. 2 When welding bipolar plates, 50 µm thick foils must be reproducibly tight and precisely welded, with a positioning accuracy of less than 100 µm for plate sizes of about 340 mm × 130 mm.

part, although repairing is not yet the automatic choice. For this reason, such repairs can take from several hours to a few days, and, in the case of aircraft turbines due to strict quality assurance, up to three weeks. Since practically every damaged item is unique, the aim is to develop an adaptive and, if possible, self-learning process chain to make the repair process cost-efficient.

Laser cladding is the preferred technique for repairing turbine blades whereby the monitoring of basic characteristic data is now carried out as standard. The geometry of turbine blades is particularly challenging: a laser beam cannot be guided over the component at a constant speed due to the tapered shape and tight curve. Likewise, the material thickness varies, which leads to different run-out zones and, in the worst case, causes the molten pool to run away. Tracing is essential in order to avoid skewed components, as it can be used to determine exactly when the process no longer meets the desired parameters and corrective action must be taken.

Here, the joint project called "Transformation of complex product development processes into knowledge-based services for generative manufacturing – TWIN" aims to automate the repair process. TWIN documents the process variables and component properties that are important in production. This ultimately reduces personnel and material costs by avoiding failed attempts, and provides deeper insights into the manufacturing processes and its problems. Automation solutions can be designed in this way, and the first systems are already running largely autonomously.

Monitoring the basic characteristics of a 3D printer, such as oxygen content, temperature, laser power and powder quality, is already standard. Other possible sources of error in laser melting are, for example, non-optimal scan speeds, or too much or too little energy input in the powder bed. The latter leads to powder that is not melted, which shows up in the form of irregularly shaped pores. A too high energy input causes the melt to boil and gas bubbles to form.

Project participant Thomas Kimme, CEO of Laservorm: "With the NC-integrated tracing function, our company has created a tool for real-time data logging in time slices of 800 µs (standard) and 10 µs (optional). This allows fast laser processes, such as welding with a feed rate of 1 m/s, to be recorded with sufficient accuracy and in relation to workpiece coordinates." The convenient thing is that the user can now individually define which parameters are recorded in which time slices and windows. This means that tracing can be effectively adapted to the application purpose and help to better understand and control processes.

Parallel to the TWIN project, high-performance tracing and data transfer in real time was successfully carried out and tested with the welding of bipolar plates. This fast transfer of data provides the basis for AI-supported analysis of the data, enabling a real-time reaction to fluctuations in production and early prevention of errors. For this, the entire transmission chain must work and react fast enough, often in the range of milliseconds.

The data libraries generated by the data make it possible to draw conclusions about the processing of new materials and structural shapes, and to anticipate the actual assembly-build process by simulation, thanks to 'digital twin'.

Reproducible high-performance welding of bipolar plates

In a sub-project of TWIN, Laservorm has developed its new tracing technology. The background is that heavy-duty traffic generates about 25 percent of the CO_2 emissions of the transport sector, which must be drastically reduced according to EU regulations. The fuel cell, which generates electrical energy and heat from hydrogen and oxygen, and thereby allows CO_2-free driving with a long range and fast refueling, is therefore becoming increasingly interesting for buses and heavy-duty transport.

A fuel cell stack consisting of 350 to 500 cells is required for an output of 100 to 150 kW. Between these units are bipolar plates that supply the necessary reaction gases and remove the resulting water. The bipolar plates account for up to 45 % of the production costs.

In addition, the manufacturing of the bipolar plates with their complex flow technology, tight tolerances during forming and high demands on the welding of the half-shells is problematic. The 50 µm-thick foils must be reproducibly

Company

Fig. 3 With tracing, the user can define which parameters are recorded at which time, and that these parameters are documented based on location.

tight and precisely welded. The required positioning accuracy of less than 100 µm for plate sizes of about 340 × 130 mm is another challenge. In addition, bipolar plates must not warp after they have been welded.

"It is now time to research manufacturing processes suitable for large-scale production so that fuel cells can be put on the road in significant numbers," says Dr Ludwig Jörissen, head of fuel cell research at the ZSW in Ulm. According to his estimate, it would be possible to produce about 10,000 units/year/standard of fuel cells. And he laments the poor availability of fast inline measurement and testing methods for robust and defect-free large-scale manufacturing. An essential step on this path is the new tracing technology.

Tracing technology ensures quality

The parameters must be just right for a laser system to weld fine structures, as required for bipolar plates at up to 1 m/s (Fig. 2). The new tool provides the data for this by closely monitoring the process and determining how changed parameters affect the welding result. A special feature of the system is that the associated workpiece coordinates are also recorded.

"What is new about this tracing is that the user can define which parameters are recorded at which time and that these parameters are documented in relation to the location. Previously, this was only possible through our machine setter and could not simply be redefined on site," Kimme says, pleased.

The technology is directly integrated into the control system and eliminates the need for an external data logger. The new method reliably collects and stores all process data from the laser process at time intervals of up to 800 µs. Among other things, the system records laser power, feed rate and position of the laser head, plus the exact coordinates of the spot where the laser beam hit the part. In this way, defects can be precisely determined in the case of quality problems, and the data obtained forms the basis for future AI-based process control.

The tracing technology consists of two software components. The TracingClient is integrated directly into the controller and allows the values of all components connected to the controller to be read out. The TraceServer records the tracing data. This system can be integrated into the plant or operate externally. "This tracing technology is a development of our company and therefore best adapted to our systems. This guarantees high performance, and the correspondingly high data throughput allows tracing data to be recorded without delay, even for very complex, fast laser processes," Kimme says.

The tracing data is provided independently of the respective system, e.g. in a csv file, for further processing with tools such as KNIME, MATLAB or Scilab, or via cloud-based KIAnalysis platforms.

Documentation of control interventions

In adaptive processes such as laser cladding, the different measured values can be used to individually adjust the processing of each component. Thanks to coordinate-related recording of the data, possible trends and creeping errors and their causes can be detected at an early stage (Fig. 3). This means that during quality control, it is still possible days later to find out how each component was processed as well as why and where quality problems occurred. For AI to be able to guide the control processes, it needs the data in sufficient quantity in real time. This provides a solid basis for reacting directly to fluctuations in production in the future and counteracting the occurrence of errors at an early stage, not only for bipolar plates or turbine blades, but for all laser processes.

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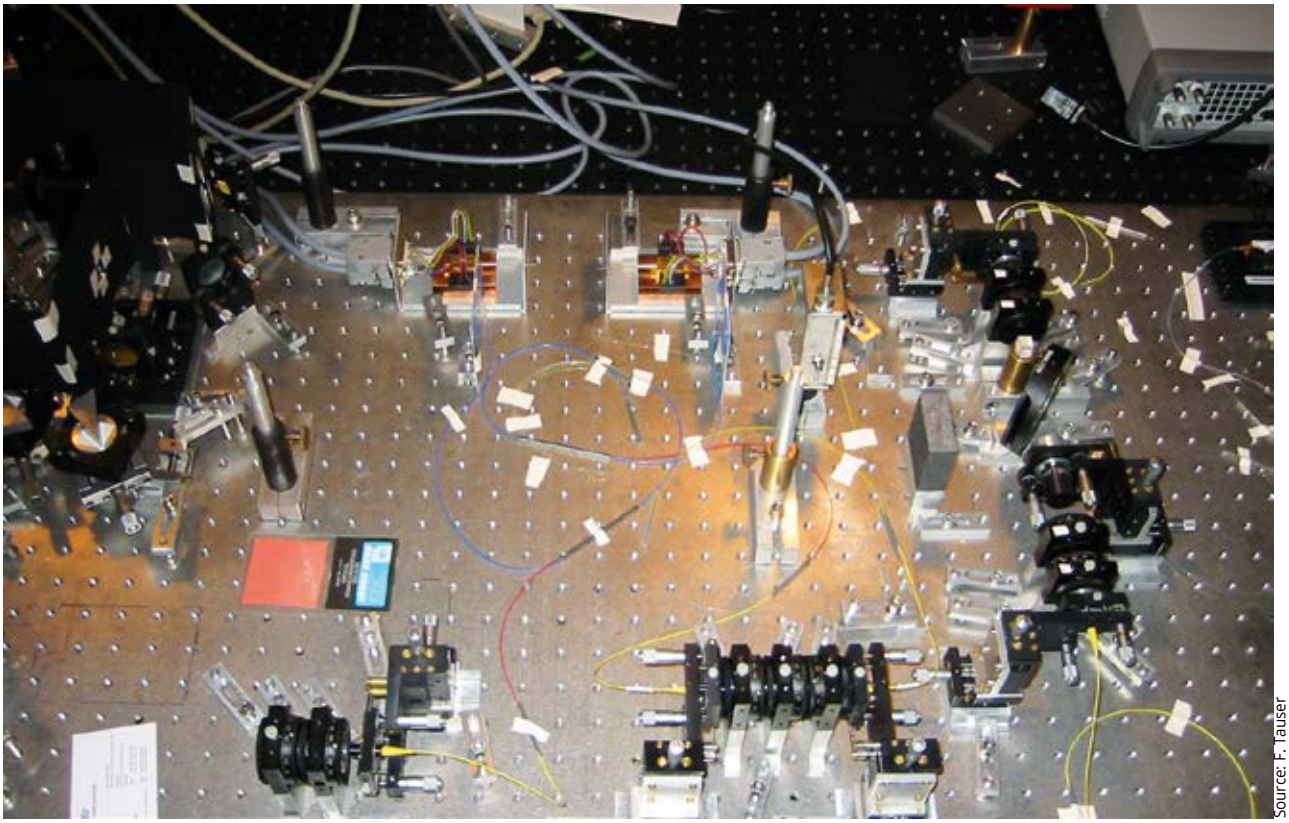
Beneficial cooperation

The transfer of femtosecond fiber laser technology from the University of Konstanz to Toptica demonstrates a successful shift from research results to a real product

Wilhelm Kaenders, Alfred Leitenstorfer, and Florian Tauser



Source: F. Tauser

Motivated by the first laboratory demonstration of a self-referenced femtosecond frequency comb using a fiber laser [1], Toptica Photonics and the Ultrafast Phenomena and Photonics research group of Alfred Leitenstorfer at the University of Konstanz have established a direct link of collaboration since 2004. This long-standing knowledge transfer has now been recognized with the Technology Transfer Prize of the German Physical Society (DPG).

Florian Tauser, who presented the technology during the award ceremony, was the PhD student who conducted the first experiment, which took place at the Technical University of Munich. After completing his PhD, he moved to Toptica Photonics where he helped to set up a new team for femtosecond fiber laser technology. The ongoing collaboration not only involves aspects of fundamental research of interest to both parties, but also the subsequent technology transfer, occasionally even supported by graduates moving from the University of Konstanz to Toptica after completing their academic work. Amongst the initially transferred technical concepts, nonlinear frequency conversion in highly nonlinear fibers has played a key role. It allows the creation of continuously tunable and extremely short light pulses with a duration of just a few femtoseconds across the entire near infrared and visible spectrum [2]. This principle provides the basis for a wide array of applications, for example in precision measurement technology, spectroscopy and microscopy. The knowhow and technology at the heart of the award has since been protected by three patent families.

▲ This laboratory setup from 2003 was used for the first self-referenced detection of the phase shift frequency f_{CEO} of a frequency comb from a mode-locked fiber laser [1].

Central to this year's award of the DPG Technology Transfer Prize is the recognition of the breakthrough development of a passively phase-locked frequency comb from the second phase of the collaboration [3]. The emission spectrum of a mode-locked laser consists of equidistant lines spaced at the pulse repetition rate f_{rep}. The entire set

The commercially available frequency comb system can be optionally extended to superimpose a cw diode laser on the frequency comb. Other components include beat detection and lock electronics. (Source: Toptica)

of equidistant lines is displaced relative to the origin at $f = 0$ by the carrier-envelope offset frequency f_{CEO}, due to the difference between the phase and group roundtrip time within the laser resonator. While f_{rep} is easily accessible with a fast photodiode monitoring the pulse train, the measurement of f_{CEO} used to be the long-missing piece required for determining frequency of the comb lines within the optical frequency comb. The first such determination of f_{CEO} was recognized in 2005 by the award of the Nobel Prize for physics to John Hall and Theodor Hänsch. Since then, full control over f_{rep} and f_{CEO} has made it possible to determine optical frequencies with high accuracy through electronic counting in the radio frequency range.

Building on this, the Leitenstorfer group managed to eliminate the carrier-envelope offset frequency f_{CEO} completely with an all-optical method in 2011 [3] by using a difference frequency mixing process within an extremely broad frequency comb. The resulting offset-free 'difference frequency comb' reduces the measurement of any chosen optical frequency now to the much simpler matter of electronic frequency counting while removing the necessity to detect and actively control f_{CEO}.

Toptica introduced the first difference frequency comb to the market in 2016 based on this scheme, after intensive research, development and testing, carried out in close collaboration with the group for Ultrafast Phenomena and Photonics at the University of Konstanz. In addition, Toptica has thereafter developed a platform suitable for serial production. As is so often the case with innovations, it was first necessary to overcome the skepticism of the users who were accustomed to significantly more complicated but well-established technologies. Further fundamental research at the university also helped to build acceptance among the intended user community; for example, a fully stabilized version of the frequency comb was realized [4], and its noise characteristics were measured and quantitively understood [5]. The relative deviation of the phase shift frequency from 0 Hz in the difference frequency comb was found to be below 10^{-21}, even in a typical laboratory environment without strict control of external influences [6]. This demonstration helped not only to improve the commercial product of Toptica, but also increased trust in the solution as well as the demand for the product by potential users.

Over the course of the long-standing collaboration, the general understanding of the phase noise of these systems has improved immensely. Most recently, this knowledge has resulted in the realization of a fiber-based frequency comb with a free-running line width below 5 kHz, starting from the

Company

Toptica Photonics

From a start-up in 1998, the company has developed over the last 25 years into an international corporation, including subsidiaries in France, USA, Japan and China. With 480 staff, the company focuses today on the development and production of laser tools for industry and academia, in particular for applications in biophotonics, test and measurement and most prominently in quantum technology. Toptica has become one of Europe's leading high-tech laser and photonics companies, and has its headquarters near Munich, Germany.

www.toptica.com

Institute

Center for Applied Photonics, University of Konstanz

The Center for Applied Photonics (CAP) is a transfer platform at the Department of Physics of the University of Konstanz. It serves two central goals: (i) the direct transfer of optical technology from fundamental research into high-tech industry (ii) the training of highly qualified individuals for the photonics sector and mentoring of young leaders in academia. The main areas of expertise of CAP are femtosecond lasers, frequency combs and optical phase control, field-resolved infrared technology and nanophotonics.

www.physik.uni-konstanz.de/cap

radio frequency f_{CEO} and all the way up to the upper end of optical emissions at around 300 THz [7]. The corresponding oscillator technology is currently being integrated into the difference frequency comb.

Today, 25 years after Toptica's foundation, around 490 employees generate an annual turnover of more than 120 million euros worldwide. A strongly growing share of this revenue stems from products that have their origin in the technology from Konstanz. The difference frequency comb approach provides quality and ultimate technical precision and has reached the stage of maturity as a commercial product line. The turnover generated with this premium component has risen by a factor of seven over the last four years. In view of the accelerating adoption of the technology, it is easy to anticipate further growth over the coming years.

In the eyes of Prof Leitenstorfer, one advantage of the ongoing collaboration lies in the fact that the financial support provided by Toptica can be assigned flexibly – an extremely attractive aspect in the age of 'lean' base funding at universities. This allows for implementing ideas much more quickly than through uncertain and lengthy applications for third-party funding. The regular knowledge exchange with the company also provides technical benefits to his team of basic researchers, e.g. due to the ability to tap into a vast pool of experience in technology development and production. In addition, the young scientists in his research group benefit from exposure to the needs of a company and its internal organization.

Florian Tauser appreciates that at Toptica, right from the beginning he was teamed up with excellent engineers, without whom his laboratory setup would never have made the transition to a real product. It was also important that the company already had an established sales network in the scientific community and was present at all relevant trade shows and conferences. This helped a lot to reduce the hurdles for market entry. However, he underestimated how difficult it would be to convince potential customers of the benefits of a new technology. Gaining acceptance over an established technology is always difficult. To this end, the fundamental research projects in Konstanz and the resulting publications have long been an outstanding endorsement for Toptica's new products.

In the view of Wilhelm Kaenders, questions of licensing technology in academic research come into play often far too early and often block any potential attempts at sustainable technology transfer already at the start. A real long-term perspective from both sides should be the goal, since in the end, technology transfer happens through people. Good cooperation costs time and money, but the company also gains new employees, for example. In turn, through the progression of research results into mature technology, also the research group gains access to robust research equipment and becomes more attractive for other researchers. Mutual trust, credibility and visibility, both internally and externally, are the rewards for both sides of the transfer.

DOI: 10.1002/phvs.202300026

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Wilhelm Kaenders received a physics diploma from University of Bonn and Imperial College, London in 1989. He finished his PhD in physics at the University of Hannover in the field of laser-cooled atoms under the guidance of Prof Meschede by devising and building magnetic atom optics. Wilhelm is a member of OSA (Fellow), SPIE (Fellow), and the German Physical Society DPG. He has been chairman of the Laser World of Photonics advisory panel since 2009. His scientific work was recognized with the Berthold Leibinger Innovation Award in 2016 and the OSA Paul Forman Award in 2017.

Alfred Leitenstorfer obtained his PhD at the Technical University of Munich (TUM) in 1996. After joining Bell Labs in 1997, he completed his postdoctoral thesis in experimental physics at TUM in 2000. He has been a full professor since 2003 and heads the Center for Applied Photonics at the University of Konstanz. Leitenstorfer was awarded the Rudolf Kaiser (2000), Arnold Sommerfeld (2000), Ludwig Genzel (2010) and Kenneth J Button (2020) prizes, received an ERC advanced grant in 2011 and is an Optica Fellow since 2013. His research concentrates on quantum phenomena at elementary scales of time and space.

Florian Tauser studied physics at the University of Constance and at the Technical University of Munich. In 2004, he gained a PhD degree under the supervision of Prof Leitenstorfer. He subsequently joined Toptica with the aim of transferring new laser technology from his academic research into real-world products. After extensive spells with two of the largest laser manufacturers worldwide, Florian returned to Toptica in 2020. Today, he is responsible for the company's R&D activities in ultrafast fiber lasers.

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New lasers for climate research

How do you measure the temperature of individual atoms at an altitude of ninety kilometers?

Source: Fraunhofer ILT / Ralf Baumgarten

Weather reports, climate models, or rocket launches – they all need precise data from the atmosphere. Scientists can use lidar (light detection and ranging) systems to shoot laser beams into the sky to acquire such data. The backscattered light can be used to calculate wind and temperature data at altitudes of up to 100 km. A team from the Fraunhofer Institute for Laser Technology ILT and the Leibniz Institute for Atmospheric Physics IAP has developed a portable lidar system that works autonomously. In the future, such systems could be mass-produced and combined into networks to provide high quality climate data.

An October evening on the beach at the Baltic Sea: although the water is amazingly clear, Josef Höffner chooses to look up. Where others see only sky and clouds, he sees a huge map opening up above him. "We don't know much about the upper atmosphere in particular yet," he comments. "There are still plenty of blank spots on the map." Exploring these spots is his job – he is an atmospheric physicist.

He has already traveled a lot with his research: he has been halfway around the world on the ship Polarstern for measurement campaigns, and has even been to Antarctica, to Spitsbergen and Andoya in northern Norway. "The polar regions are the most exciting for atmospheric research because that is simply where you see the most." When Josef Höffner is not traveling, he conducts research at the Leibniz Institute for Atmospheric Physics IAP in Kühlungsborn on the Baltic Sea. Perched on top of a knoll, the research buildings overlook the sea from the top of gentle hills.

At night, laser beams shine in the sky above the institute. "Sometimes, the local newspapers contact us because people suspect UFOs," Höffner says, amused. "Yet these are just our lidar systems." The researchers in Kühlungsborn have been using their lidar and radar systems since the mid-1990s, and now have several teams.

Fig. 1 Josef Höffner studies the different layers of the atmosphere at the Leibniz Institute for Atmospheric Physics IAP in Kühlungsborn on the Baltic Sea.

Does it get colder with altitude?

Lidar systems send their beams through the atmosphere to heights of over 100 km. They essentially pass through three layers (Fig. 2): troposphere (up to about 15 km altitude), stratosphere (up to about 50 km), and mesosphere (up to

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about 90 km). The height of the layers depends mainly on the solar radiation. However, the height also varies with the season or the geographical location.

The boundaries between the layers are defined by an intriguing phenomenon: our experience tells us that temperature decreases with altitude. Between the layers, however, this reverses: in the stratosphere the temperature increases with altitude! Between strato and mesosphere the temperature gradient reverses again as it gets colder. The layers where the temperature gradient reverses are called pauses, i.e. tropopause, stratopause and mesopause.

Josef Höffner is particularly interested in the uppermost layer, the mesosphere. The air pressure at its upper end is about one millionth of what humans are used to. Yet there are still plenty of particles at that altitude: "That is the altitude where the nose of spacecraft starts to glow on re-entry." The same is true for meteors: many of them burn up in the mesosphere, leaving behind metal atoms that help atmospheric physicists enormously in their work.

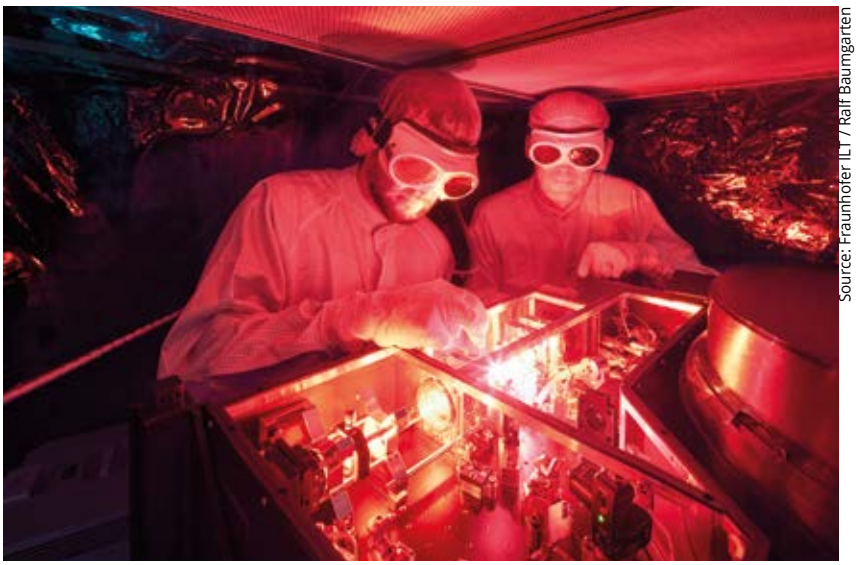
"We excite these atoms in the atmosphere with the lidar laser; potassium or iron for example," explains Höffner. The particles reflect the light back, albeit slightly altered; the physicist refers to this as scattering effects. The backscattered light is captured by telescopes in the lidar system on Earth where variables such as temperature and wind speed can be derived from the spectra. The altitude results from the transit time of the laser pulses, and the concentration of particles at altitude from the number of special photons.

What is happening in the ocean above us?

This roughly explains the tools of atmospheric physics, but what is there to measure up there? "A lot," Höffner answers succinctly, "and we are discovering more and more." To better understand the processes 'up there', one can think of the atmosphere as an ocean where there are waves, currents and tides. None of it simply disappears – every wave nudges another wave, and leads to currents because everything is in motion day and night. The boundaries between layers rise and fall, and layers influence each other.

Unlike in the sea, however, the tides in the sky are caused by the sun: it heats the air on one side of the earth and the air rises, while it cools and sinks on the other side. Currents and waves exist in the same way: so-called gravity waves are particularly important for the exchange between the lower and upper atmosphere. They occur, for example, when a storm hits a mountain range, the air pushes upward, and the momentum continues far beyond the troposphere up into the mesosphere. The momentum from below pushes currents that can be measured over thousands of kilometers.

With lidar and radar systems, teams on the ground can accurately measure movements in the atmosphere. Balloons do not get that high, and satellites provide only a snapshot as they fly overhead. Stationary lidar systems can measure currents along the laser beam upward virtually indefinitely. Josef Höffner traveled around the world in the 1990s with a lidar system he developed at Leibniz IAP for exactly this purpose.



Source: Fraunhofer ILT / Ralf Baumgarten

Fig. 3 The alexandrite lasers have been optimized in the laboratory to such an extent that they can operate in the lidar systems for thousands of hours without maintenance or adjustment.

A new generation of lasers as a game changer

The system took up an entire shipping container. It weighed ten tons and required 30 kW of electrical power to run. This in turn required tons of diesel in the generators on site. After all, it was the only semi-mobile system of its kind in the world, and it garnered scientific merits. However, it was too big, too heavy and required too much maintenance for greater use in the future. That is why Josef Höffner looked for new partners for laser development in the mid-2000s. He found them at the other end of Germany at the Fraunhofer Institute for Laser Technology ILT in Aachen, where they were familiar with the different types of laser and also with the latest technology to make them smaller.

"An alexandrite ring laser, with radiation in the UV to boot, that was pretty special," reports Michael Strotkamp, the current project manager at ILT. "Even our experts couldn't just take it off the shelf." At its core, the project involved replacing the laser's energy source – the flash lamps – with laser diodes, a conversion that is about as simple as replacing a turbocharged gasoline engine with an electric motor. Accordingly, it took ten years from the first discussions to the first successful mesosphere measurement with the new diode-pumped alexandrite laser.

State-of-the-art laser technology

Alexandrite is a very special laser crystal: it can be tuned over a broad spectrum from 730 to 800 nm. Unlike titanium sapphire (a much better-known laser crystal), it can also store abundant energy in the process. Thanks to these properties, it is particularly suitable for high pulse energies. However, it must be operated with an extremely narrow bandwidth for the lidar measurements. This means that only one spatially narrow mode may be pumped in the crystal, otherwise higher modes would oscillate and the laser would become spectrally more broadband. This was one of the main problems when flash lamps were used – they usually excited multiple

Fig. 4 In November 2022, the teams from Fraunhofer ILT and Leibniz IAP installed a new laser in another of the four lidar systems. (Source: Fraunhofer ILT / Ralf Baumgarten)

modes. The thermo-optical properties are not without their problems either: alexandrite was often operated at well over 100 degrees. "I have never had such a challenging laser crystal," Michael Strotkamp summarizes. "With the diodes, we could directly pump the mode volume, which solved many problems."

Alexandrite absorbs light down to the red range, which is why pump diodes are used at a wavelength of 638 nm. In the beginning, these diodes were bars with 80 W pulse peak power and a beam profile that had to be elaborately homogenized for the first prototypes. In the meantime, the Aachen researchers are using fiber-coupled pump diodes, which considerably simplify the shaping of the pump radiation.

The laser (Fig. 5) is designed as a ring resonator, i.e. there is no standing wave but a circulating laser wave. This is excited with a frequency-stabilized cw laser (seed) by oscillating a resonator mirror with a piezo element. Whenever the resonator length corresponds exactly to a multiple of the wavelength of the seed laser, it is coupled into the resonator. The principle is also called 'ramp-and-fire'. The laser is triggered via a Q-switch, which releases the circulating pulse when its energy is high enough.

The first prototype of the alexandrite laser delivered 0.15 W, at that time with two crystals but without homogenization of the pump radiation. With homogenized pump radiation, the laser delivered more power from only one crystal. Since then, the system has been significantly improved over several iterations. To save space, the beam path (2 m resonator length) is folded several times. Meanwhile, the pump radiation is delivered only via fibers, allowing the pump source to be changed without much effort. The latest pump source delivers 400 watts in pump pulses, and the laser is then operated with an output power of 2.3 W or pulses of 4.6 mJ at 500 Hz. At a 750 Hz repetition rate, it even runs with 2.7 W and 3.6 mJ pulses.

The secrets of the stardust

When meteorites burn up in the mesosphere, individual atoms are left behind and float up there for many years. "For atmospheric physics, this is an absolute stroke of luck, because apart from this 'stardust', there is not much else up there," explains Josef Höffner. For lidar measurements, various atoms or aerosols of the atmosphere are illuminated by the ground-based laser and scatter back individual photons. Measurements with the alexandrite lidar at Leibniz IAP use three main effects: Rayleigh, Mie and resonance scattering.

Rayleigh scattering is the reason why our sky is blue. It describes how light is scattered by particles smaller than its wavelength. The scattering is strongly frequency dependent, which is why blue light is scattered more than red light. That is why sunsets are red and the sky is blue. Above about 60 km altitude, the density of oxygen and nitrogen atoms becomes so small that Rayleigh scattering is difficult to measure.

Mie scattering describes the effect on light when it is scattered by particles that have a size similar to the wavelength. In the atmosphere, these are usually aerosols, i.e. dust or volcanic ash for example. Such particles occur up to an altitude of about 30 km.

Depending on the flight speed of the particles, the Rayleigh and Mie spectra are shifted by the Doppler effect. Scientists can calculate the velocity of the particles by comparing such backscattered spectra with the light from the lidar source. More precisely, the spectral shift provides a vector component of the wind speed in the direction of the laser beam. That is why the new lidar system measures with beams in five directions. In this way, the wind can be determined well even at high altitudes. The actual height results from the travel time of the laser beams; they need 0.3 milliseconds for 90 km. To ensure that each pulse can be completely evaluated before the next one follows, the system works with a laser repetition rate of up to 1,000 Hz.

The biggest challenge for laser engineers, however, is resonance scattering. It is the only scattering effect that can still be used to measure wind and temperature at altitudes of over 90 km. For temperature, individual atoms of the stardust are excited with their characteristic wavelength and the backscattered light is used to measure how much the spectrum has broadened. An electron goes up one level and falls back and, in the process, it emits a photon of the same wavelength again. However, the atoms buzz back and forth according to their

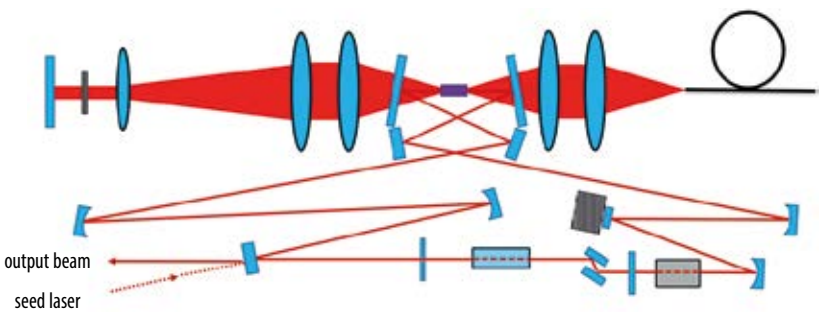


Fig. 5 The alexandrite laser is strongly folded and pumped with a fiber-coupled source (right). On the left, a mirror 'recycles' the remaining pump radiation. (Source: Fraunhofer ILT)

DOI: 10.1002/phvs.202300024

temperature, which in turn leads to a tiny Doppler shift of the emitted photon. Many of these photons arrive on earth, with their different shifts resulting in a very small broadening of the spectrum compared to the original laser radiation.

"We measure this broadening by comparing it to a gas cell here on the ground," says Höffner. For example, potassium is vaporized in a vacuum cell in the lidar system that is only the size of a thumb. The seed laser is tuned to its spectrum and its linewidth is about 100 kHz; after amplification in the alexandrite laser, it is still 3 MHz. Such precise tuning is otherwise more common in quantum computers.

"When we measure iron, we do not use a gas cell, we tune the laser right to the resonance signal of the atoms in the atmosphere." Tuning a laser ultra-precisely to the signal of individual atoms at a distance of 90 km – that is an extreme challenge even for experienced laser physicists, and yet the team from Aachen and Kühlungsborn has mastered it. The complex filter systems for evaluating the data are so good that they can filter out the few photons from the noise, even in daylight.

What is next for lidar systems?

In May and November 2022, the latest generation of lasers was installed in two of the lidar systems in Kühlungsborn and measurements up to 100 km altitude have already been demonstrated, the work being done by a constantly growing team. The work in Aachen and Kühlungsborn was funded in the 'Vertical and horizontal coverage by lidar' (Vahcoli) project. The focus is on the exploration of the atmosphere in both vertical and horizontal directions. This is achieved by one laser directed to four telescopes tilted by 30° (Fig. 6). With four such lidar systems in the network, areas of several 10,000 km^2 in the sky can be surveyed. This is then by far the most modern and capable lidar system for the middle atmosphere worldwide.

"We naturally have several ideas on how we want to develop the technology further," explains Höffner. "For example, we want to transfer the lidar systems to industry with partners from the surrounding area." The project, with a total of ten partners, will start in June 2023 as part of the RUBIN funding program. "We want to develop an amplifier stage for the alexandrite laser independently of this," adds laser expert Strotkamp.

Source: Fraunhofer ILT / Ralf Baumgarten

Fig. 6 The mobile lidar system sends five beams into the night sky. With four small and one large telescope, it detects the photons from up to 100 km altitude and provides climate data in real time.

The scientific work will be advanced in the European lidar array for atmospheric climate monitoring (EULIAA) project, which started in January 2023. The laser developers have set their sights on UV: "We want to install intracavity doubling," says Strotkamp. In other words, the laser physicist plans to install a crystal that converts the laser radiation in the laser resonator to a wavelength of 386 nm. This uses a Fraunhofer line with a low solar background and will allow iron atoms to be measured. Until now, this was only possible with much less efficient external frequency doubling. Initial tests are already promising.

Two new lidar systems will also be set up in 2023, which will ensure that the seven partners in five countries can collect climate data at a previously unattained quality in the region above 10 km where no data are currently available. "The goal is to put the lidar data into European databases in real time," explains Höffner.

"The next step would be to establish a European network for these measurements." The data would then be available for weather forecasts and climate models, because such lidar systems can measure wind and temperature distribution in real time at altitudes ranging from 10 to over 50 km, day and night. The system also provides the relevant data for rocket launches. In the long term, a satellite-based version of lidar is also conceivable: the Aachen partners have acquired a wealth of know-how for satellite-based lasers in projects such as the Merlin mission.

The importance of the work is demonstrated by research into climate change in the middle atmosphere, which has been little studied to date. "We are seeing significant changes in the mesosphere," Höffner explains. "With these new systems, we want to observe the changes continuously and over wide areas. That will have a significant impact on longer-term climate predictions." The sky will remain an exciting field of research for him: a mysterious ocean with eddies and waves, but far fewer blank spots.

The prototype of the alexandrite lasers, illustrating the conversion from (infra)red to (ultra)violet, was exhibited at Laser World of Photonics in Munich. From June 27 to 30, experts from the Fraunhofer ILT were available at the Fraunhofer joint booth 441 in hall A3 to provide information on this development and the groundbreaking applications of these technologies.

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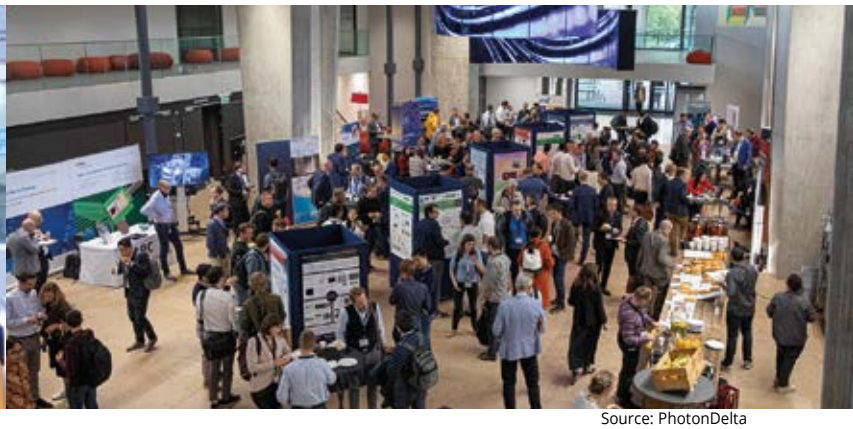
Source: Messe München



Source: PhotonDelta

September 6 – 8, 2023
CIOE
Shenzhen, China
https://cioe.cn

September 11 – 15, 2023
Schweissen & Schneiden
Essen, Germany
www.schweissen-schneiden.com

September 11 – 15, 2023
EOSAM 2023
Dijon, France
www.europeanoptics.org

September 11 – 23, 2023
EMO
Hanover, Germany
https://emo-hannover.com

September 13 – 15, 2023
LASER World of PHOTONICS India
Bengaluru, India
www.world-of-photonics-india.com

October 1 – 5, 2023
ECOC 2023
Glasgow, Scotland
www.ecocexhibition.com

October 10 – 11, 2023
Quantum Effects
Stuttgart, Germany
www.messe-stuttgart.de/quantum-effects

October 12 – 13, 2023
6th European Machine Vision Forum
Wageningen, The Netherlands
www.emva.org/emva-events

October 16 – 20, 2023
European Quantum Technology Conference EQTC 2023
Hanover, Germany
https://eqtc2023.qvls.de

October 17 – 21, 2023
Fakuma
Friedrichshafen, Germany
www.fakuma-messe.de

November 7 – 10, 2023
Blechexpo / Schweisstec
Stuttgart, Germany
www.blechexpo-messe.de
www.schweisstec-messe.de

November 7 – 10, 2023
formnext
Frankfurt, Germany
https://formnext.mesago.com

November 13 – 16, 2023
Compamed / MEDICA
Düsseldorf, Germany
www.compamed-tradefair.com
www.medica-tradefair.com

November 14 – 17, 2023
productronica
Munich, Germany
https://productronica.com

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Photonics industry thrilled by Laser 2023

Review: Laser World of Photonics, 27 – 30 June 2023, Munich, Germany

The global photonics industry met in Munich again. More than 1,300 exhibitors, of which 66 % came from outside of Germany, presented their innovations to the roughly 40,000 visitors at the world's leading trade fair of the industry. The share of these visitors from outside of Germany was nearly 55 %. World of Quantum once again met with a very positive response. The international scientific elite, including Nobel Prize winner Prof Donna Strickland, came together for six days at the World of Photonics Congress, which took place in parallel.

Source: Messe München

Impression from one of the halls of Laser World of Photonics

"Laser is finally back to the size and format where it was left before the pandemic," said Dr Wilhelm Kaenders, chairman of the exhibitor advisory board and CEO of Toptica Photonics. Show director Anke Odouli confirmed the positive feedback of the participating companies: "The mood in the halls was incredible – the exhibitors were thrilled by the quality of the visitors and the intensive discussions at their trade fair booths."

For the first time, Automatica, the leading trade fair for robotics and automation, took place in parallel. The goal to make use of the numerous overlaps between the sectors paid off: every third visitor to Automatica also came to Laser World of Photonics or World of Quantum. Dr Sven Breitung, CEO of the VDMA laser and laser systems for materials processing working group, likewise welcomed holding the events in parallel: "It is very important to us to bring together suppliers and users of laser technology as well as players from automation and robotics. From now on, the co-location offers the perfect opportunity to create new inspiration and added value between the two industries and therefore work together toward innovative solutions."

Meeting place for the international quantum community

Following its premiere in 2022, a strong second edition of World of Quantum took place with nearly ninety exhibitors and over 15,000 trade visitors in parallel with Laser World of Photonics. "We are very pleased that the platform has seen such excellent visitor numbers and received top marks in the trade fair survey," said Odouli. Points of attraction included several quantum computers and a magnetic field sensor that will control prostheses via muscle signals in the near future.

After four years, the international scientific elite were at last able to meet in person again at Europe's largest photonics congress. They included big names such as Nobel Prize winner Prof Donna Strickland, Herbert Walther Award winner Prof Rainer Blatt, and Fraunhofer ILT director Prof Constantin Häfner.

The next Laser World of Photonics and World of Quantum will take place together with Automatica from June 24 to 27, 2025, in Munich. The next World of Photonics Congress runs in parallel from June 22 to 27, 2025.

www.messe-muenchen.de

Very positive results for the 21st edition

Review: EPHJ, 6 – 9 June 2023, Geneva, Switzerland

EPHJ, the international high-precision watchmaking, jewellery, microtechnology, and medical technology show, closed the doors of its 21st edition with a significant increase in the number of visitors compared to 2022, and a quality of international trade visitors praised by the 750 exhibitors. "All our attendance indicators are up," explains Alexandre Catton, director of the EPHJ show, "particularly the number of foreign visitors. But what really stands out for me is the very positive mood and atmosphere at this year's show, which reflect a dynamic market and full order books for 2023. This is not stopping our exhibitors from keeping a close eye on market developments, based on their contacts during the show."

In concrete terms, EPHJ 2023 brought together 750 companies from sixteen different countries, a significant increase on the 700 exhibitors in 2022. The most remarkable increase, however, was in visitor numbers, with 21,780 Swiss and international trade visitors, up 21 % on 2022. A sharp increase in visitors was recorded on the first day of the show. This increase is due in particular to the greater presence of foreign visitors, from all five continents. "Some exhibitors told me that they had spent a large part of their day speaking English," explains Alexandre Catton; a sign that is not misleading.

There were a number of highlights at this 21st edition of the show, including the last day that was dedicated to job dating, to try and fill the many vacancies available in the companies at the show. Many candidates came to meet the employers.

The 2023 Exhibitors' Grand Prize was awarded to MPS Watch for its new Oscrew oscillating weight fixing system.

The EPHJ 2024 show will take place from 11 to 14 June, again at Geneva Palexpo.

www.ephj.ch

Preview: Quantum Effects

10 – 11 October 2023, Stuttgart, Germany

With a new format, Messe Stuttgart is creating a forum to bridge the gap between science, start-ups and industry, as well as to make innovative quantum technologies visible in Europe: Quantum Effects. The trade fair and conference for quantum technology premiers on 10 and 11 October 2023 with Bosch Quantum Sensing as hosting partner, the Quantum Business Network QBN as congress partner, and QuantumBW as additional supporter.

To promote the development of a European ecosystem and to bridge the gap between science, start-ups and industry, the trade fair and conference for quantum technology will focus on four pillars in this field: "Computing and Enabling Technologies", "Software", "Sensors" and "Communication". Hosting partner Bosch Quantum Sensing is also playing a key role in shaping the trade fair and conference.

Quantum Effects is sponsored by the Baden-Württemberg Ministry of Economic Affairs, Labor and Tourism. Under the umbrella QuantumBW, the state of Baden-Württemberg bundles and strengthens research activities and initiatives from science and industry in order to bring quantum research into application more quickly, and giving structure to the already existing network of universities, research institutions, global players and start-ups.

The Quantum Business Network QBN is the fastest-growing organization promoting networking, business creation and the development of organizations working on quantum technology and its value chains, currently with over 70 members worldwide.

Source: Wiley

Partner panel for Quantum Effects (l-r): Guido von Vacano (Messe Stuttgart), Prof Jena Anders (U Stuttgart), Dr Katrin Kobe (Bosch Quantum Sensing), Roland Bleinroth (Messe Stuttgart), Prof Joachim Ankerhold (U Ulm), and Adrià Gómez Olivella (QBN)

By combining an exhibition, conference for science and industry users and the start- up pitch and careers areas, Quantum Effects offers an attractive program for the trade audience, with highlights such as the forum for presenting exhibitors' showcases and application examples.The centerpiece is the first-class conference program, which includes scientific lectures for experts and user presentations for industry, management and politicians. Beyond this core element, the accompanying program of forums, workshops, networking and career area, start-up pitches, and art installations rounds off the first edition of Quantum Effects.

The fair's main target attendee groups include representatives of small and medium-sized enterprises, as well as large companies. The trade fair combined with a conference is aimed equally at companies that have already initiated quantum technology projects and those that are not yet active in the market, but are interested in building up expertise in this field. Students and academics from universities and academies are also part of the target group, as are political leaders at state, national and EU level.

The Quantum Effects Award, which will be presented for the first time during the Quantum Effects 2023 exhibition and conference for quantum technology, acknowledges excellent innovations that connect the classical and quantum worlds, are used in different industries, enable individual services and open up new perspectives. This also applies to components with the help of which quantum technologies and solutions are significantly advanced.

www.messe-stuttgart.de/quantum-effects

Get your tickets for the QBN Quantum Industry Summit now!

This premier international business and tech conference alongside Quantum Effects will bring together over 500 international leaders, experts, and stakeholders to address the pressing demands and challenges facing the quantum industry, promote European sovereignty in the global quantum landscape, and drive innovation and industrialization of quantum technology.

The conference will feature 50+ speakers across four parallel tracks, each with its own unique focus:

- Politics, Business & Ecosystem
- Quantum Technologies & Supply Chains
- Industry Applications & User Access
- Biz & Investment Opportunities

In addition to the extensive conference program, attendees will have also access to the Quantum Effects exhibition, Europe's first trade fair for quantum technology. Tickets for the conference grant access to the exclusive Networking Night on October 10.

To join the Call for Early-Stage Quantum Ventures Investment Forum, please contact: startups@qbn.world. For more information about the QBN Quantum Industry Summit and registration, please visit

https://qbn-summit.com

Preview: Schweissen & Schneiden 2023

11 – 15 September 2023, Essen, Germany

The industry giants have all booked their stands for the world's leading trade fair for joining, cutting and surfacing. In addition to Lincoln, ESAB, Microstep, Abicor Binzel, EWM, Fronius, Messer Cutting, Voestalpine and many others will also be presenting their products and services to the international trade audience at Messe Essen. Furthermore, numerous niche players, hidden champions, start-ups, associations and research institutions have confirmed their participation in the fair. Messe Essen project manager Christina Kleinpaß recalls from the booking period: "We could feel the catch-up demand in the industry, everyone can hardly wait to finally meet again. In this respect Schweissen & Schneiden, as the number one event, is the platform for innovations and networking."

Optimized hall layout guarantees short distances

An optimized hall layout will offer exhibitors and visitors numerous synergies for their participation in the trade fair. So exhibition halls 1 to 5 are reserved for companies from the welding sector. In halls 6 to 8, companies will be presenting their cutting products and services. The appropriate equipment, filler materials, surface technology, services and digitization offerings are available directly in the respective exhibition areas. "This guarantees short distances and a perfect fit," explains Christina Kleinpaß. "Our visitors will find products and the matching solutions in the direct vicinity. In this way, we offer exhibitors great potential for their presentation and minimize spreading loss."

www.schweissen-schneiden.com

Preview: Blechexpo / Schweisstec 2023

7 – 10 November 2023, Stuttgart, Germany

Together with the 9th Schweisstec international trade fair for joining technology, the 16th Blechexpo international trade fair for sheet metal working will serve as the meeting place for global players in the field of sheet metal working. Nine halls are fully booked out at the Stuttgart Exhibition Center. The trade fair duo presents complete process sequences for modern, future-proof sheet metal processing, and is highly acclaimed amongst the experts. An impressive supplementary programme including the presentation of the "best Award 2023", the "Blechexpo Steel Convention 2023", the "futureSteel" congress and the expert forum rounds out the trade fair's offerings.

The range of topics covered by Blechexpo/Schweisstec includes efficient process methods for modern laser technology, fully automated robotic sheet metal processing machines, precision tools and systems for punching, bending, braking and forming, as well as innovative micro-waterjet cutting technologies. Not least of all, the current shortage of qualified production personnel is fueling further automation across the board, for example in materials handling and machine operation. The planning, implementation, and analysis of production processes are becoming more efficient thanks to advancing integration of production data. "Expert visitors at Blechexpo/Schweisstec will experience the entire process chain for sheet metal working," emphasizes project manager Georg Knauer.

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

Preview: Formnext

formnext

7 – 10 November 2023, Frankfurt, Germany

Formnext has hit the ground running in 2023 with the highest number of registrations. Already in spring, more than 550 companies had signed up to attend the world's leading trade show for AM technology and next-generation manufacturing; almost two thirds of them from outside Germany. To meet this enormous demand from the community, Formnext has developed a range of specialized offerings for the November show and is increasingly becoming a hub for additive manufacturing 365 days a year.

The continued momentum and confident mood of the AM industry are reflected in Formnext's registration figures. The AM world's movers and shakers who have already registered to exhibit at the in-person event include companies such as 3D Systems, Additive Industries, Arburg, BigRep, Carbon, DMG Mori, Dyemansion, Dyndrite, EOS, EPlus, Farsoon, Formlabs, GE Additive, GKN Sinter Metals Components, Hage 3D, Hexagon, HP, Keyence, Markforged, Massivit, Nexa3D, Open Mind, Prima Additive, Renishaw, Ricoh, Roboze, Rösler, Sandvik Additive Manufacturing, Shining 3D, Siemens, Sisma, SLM Solutions, Stratasys, Trumpf, Velo3D, Voxeljet, and Xjet. In addition, numerous new companies as well as renowned international groups along the entire process chain will showcase what they do, including BASF, Bosch, Evonik, Höganäs, Linde, Nikon, Oerlikon, and Praxair. Contract manufacturers specializing in 3D Printing are often the entry point for users into additive manufacturing. So far, FKM Sintertechnik, Jabil, Materialise, Promod Prototypenzentrum, and Quickparts have registered.

For the first time, this year's conference program will be held across three different stages in the exhibition halls.

https://formnext.mesago.com

Preview: Medica + Compamed 2023

13 – 16 November 2023, Düsseldorf, Germany

The internationally leading trade fairs for the medical technology sector and its suppliers, Medica and Compamed in Düsseldorf, were able to log a notable increase in the number of exhibitors for 2023 and a strong boost in the number of visitors in the past year. "The rate of repeat bookings is very high, reflecting customer feedback immediately following the 2022 editions. Contact with international professional medical suppliers is of enormous importance for many companies, for example. And this target group has demonstrated a renewed presence among visitors again," explains Christian Grosser, director health and medical technologies at Messe Düsseldorf. In 2022, the two fairs recorded a total of 81,000 visitors (2021: 46,000) with an international proportion of 75 %.

Grosser goes on to emphasize a certain unique characteristic of Medica and Compamed which the over 5,000 exhibiting companies at the latest trade fairs are deeming more and more important: "Both events with their unique mutual influence are the location where we focus on the topic of the entire supply and value chain of medical technological products – including their assembly parts and product development, aspects of manufacture, up to and including downstream services over the lifetime of the product. One factor here is business and reliable partnerships within the medical technology industry. In the face of current global political challenges, this has become very important. The necessary goal is to create a secure foundation for your own business."

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

Preview: W3+ Fair Jena

29 – 30 November 2023, Jena, Germany

The W3+ networking fair and conference for enabling technologies is coming to a new location. Numerous regional and national exhibitors will be present and showcase their current precision technologies, from which also high-tech products from everyday life emerge. More than 130 companies and partners are taking part – from Thuringia, other federal states and from abroad. The exhibitor range includes products, services, innovations and solutions in microsystems and nanotechnology, measurement technology, mechatronics and precision mechanics, systems and product engineering, materials selection, production and much more.

The free accompanying conference en-tech.talks also aims to provide impetus. Rafael Laguna de la Vera from the Federal Agency for Leap Innovations Sprind will open the Innovation Start-up Show with his keynote speech, in which young companies will present their ideas. ASML, Zeiss, Jenoptik, Micro-Hybrid and others are sending renowned speakers to present the latest technological developments in the photonics region of Thuringia. In addition, an EPIC Techwatch and a lecture block on the topic of medical technology are planned.

Large and small companies such as Jenoptik, Zeiss, Schneider, Opto-Tech, Fisba, Dopa, Sill Optics, WZW Optic, TNO, Lasos, Layertec, JAT Jenaer Antriebstechnik, POG, Fraunhofer IOF and FEP, Spaceoptix, Acktar, SIOS, Batop, Materion Balzers Optics, PI Physik Instrumente, Mersen, and IMT will showcase their products and services on site.

https://w3-fair.com

Save the date: AKL'24

17 – 19 April 2024, Aachen, Germany

The Fraunhofer Institute for Laser Technology ILT invites the laser community to the 14th International Laser Technology Congress AKL in Aachen from April 17 to 19, 2024. Laser users and manufacturers as well as laser developers from different areas of the laser industry will have the opportunity to exchange information about the latest developments in applied laser technology in production at AKL'24.

Companies are constantly looking for new ideas and technologies to better position themselves in times of a strong competitive environment. The necessary information edge in applied laser technology is offered to the more than 500 participants by AKL'24. The main topics of the more than eighty lectures range from laser material processing in the macro and micro range, laser beam source development, additive manufacturing to process monitoring and digitalization. In addition, the optional technical forums "Digital Science & Photonic Production", "Quantum Technology & Photonics" and "Laser Surface Technology" provide more in-depth expert knowledge. Between the lectures, the conference-accompanying exhibition with around fifty laser manufacturers and system or component suppliers offers the opportunity to establish contact with proven experts in the laser industry. The application laboratories of the Fraunhofer ILT with the latest highlights of laser research can also be visited during the "Laser Technology Live" event – networking at its best!

www.ilt.fraunhofer.de
www.lasercongress.org

Components and accessories

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

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www.termotek.de
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Extraction systems, AIR PuriFication

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Fax: +49 (0) 7346 / 8422
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Laser beam sources: Solid-state lasers

Diode lasers, for material processing

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56218 Mülheim-Kärlich
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www.laserline.com, info@laserline.com

Fiber lasers up to 100 W

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Bräunleinsberg 10, 91242 Ottensoos
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info@photon-energy.de, www.photon-energy.de

Nd:YAG lasers, diode-pumped

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

Nd:YAG lasers, pulsed

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Nd:YAG lasers, up to 500 W

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Short-pulse lasers

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Laser optics and components

Beam splitters

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info.mbo@materion.com
www.materion.com/balzersoptics

Filters, optical

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

Free-form optics

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Fax +49 (0) 89 800 746-199
info@scanlab.de
www.scanlab.de

Microoptics

Zünd precision Optics ltd
Prismastr. 5
CH-9444 Diepoldsau
Tel. +41(0)71 737 74 00
Fax +41(0)71 737 74 10
info@zuendoptics.com
www.zuendoptics.com

Mirror coatings

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www.materion.com/balzersoptics

Mirrors

B&M Optik GmbH
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+49 (0) 6431 9860 – 0
info@bm-optik.de / www.bm-optik.de

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

Mirros, UV

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

Optical Components

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+49 (0) 6431 9860 – 0
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Balzers, Liechtenstein
Phone +423 388 92 00
info.mbo@materion.com
www.materion.com/balzersoptics

Windows, optical

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

Material processing systems

Laser welding

Evosys Laser GmbH
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www.evosys-laser.com
sales@evosys-laser.com

LPKF WeldingQuipment GmbH
Tel. +49-911-669859-0, Fax: -77
www.lpkf-laserwelding.de

Marking systems

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

Optical components

3D Anti-Glare-Spray

Helling GmbH, 25436 Heidgraben
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www.essentoptics.com

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