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PhotonicsViews

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PI

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Advances in active alignment engines for efficient photonics device test and assembly

SPECTROSCOPY

Addressing transferability and stability in Raman spectrometers

OPTOELECTRONICS

Manufacturing waveguides for AR devices with ion beam technology

TECHNOLOGY REPORT

Smart photonic sensors transforming the automotive, agriculture, and healthcare sectors

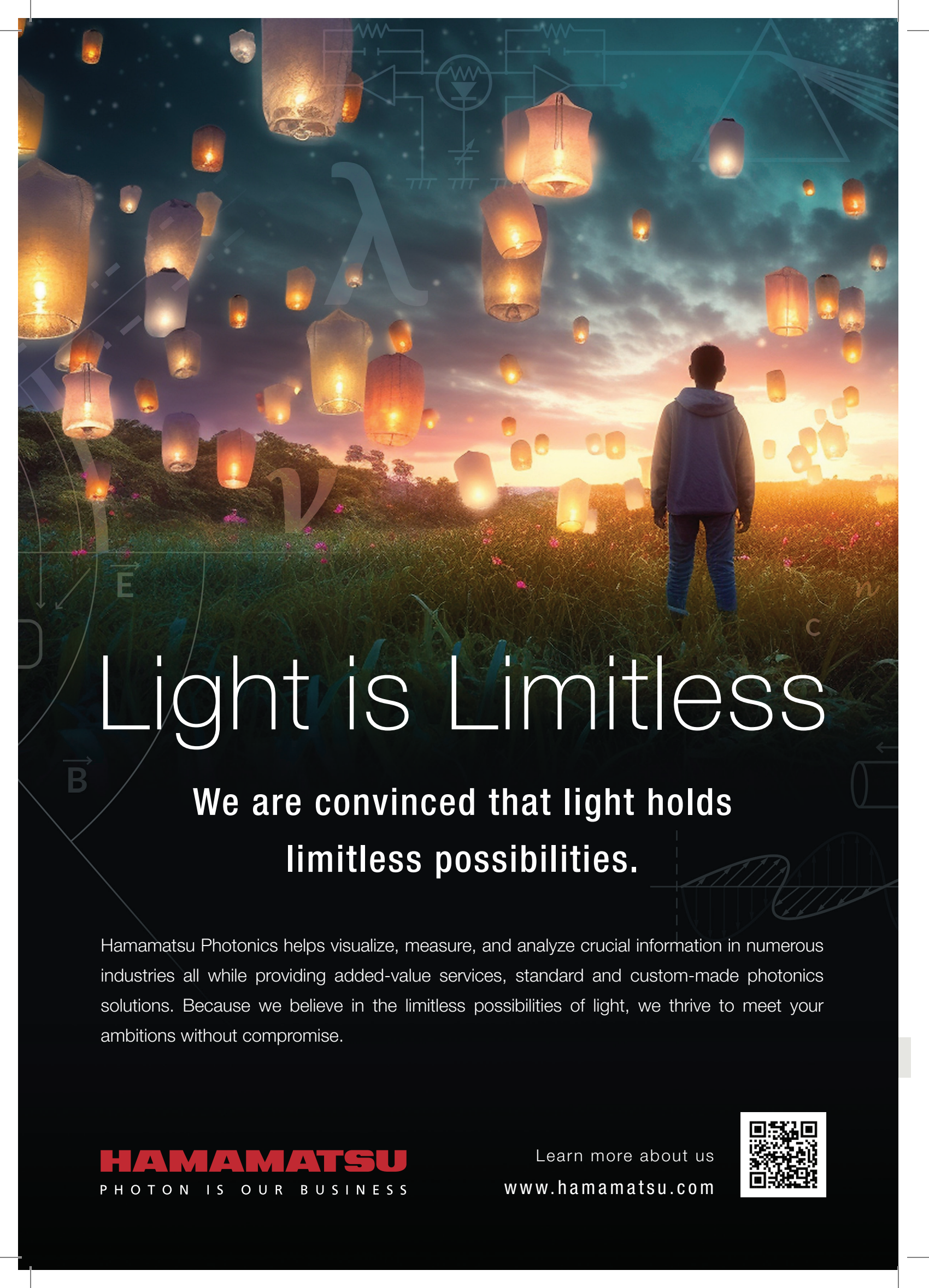
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Photonics outlook for 2025: Illuminating the path to innovation

As we start 2025, the photonics industry stands on the cusp of a transformative era, poised to illuminate new frontiers across various technological landscapes. Despite the multifaceted challenges that have characterized recent years, the resilience and adaptability of the photonics sector continue to shine through, offering a beacon of hope for the future.

Significant trends for 2025 will include the continued evolution of augmented and virtual reality (AR/VR) systems, alongside remarkable advancements in medical imaging and biosensors. Innovations in sensor technology, particularly single-photon avalanche diodes (SPADs), are set to redefine our interaction with digital environments and revolutionize healthcare diagnostics. These developments will play a pivotal role in enhancing the immersive experience of AR/VR systems, offering improved depth perception and low-light performance, while also offering unprecedented resolution and real-time capabilities for medical diagnostics.

The integration of photonics in data centers and the emerging 6G networks is set to accelerate in 2025, addressing the ever-growing demands for high-speed communication and data processing. Next-generation optical transceivers will become the backbone of data centers, offering higher bandwidth, lower latency, and improved energy efficiency, while photonics photonic integrated circuits and free-space optical communication systems are key components to realizing the full potential of 6G networks.

Finally, I believe 'green photonics' is also poised to take center stage in 2025, focusing on energy-efficient systems for renewable energy, lighting, and communication. Photovoltaic technologies will see significant advancements, with new materials and designs improving solar cell efficiency. Photonics-based sensors will also play a crucial role in optimizing renewable energy systems and smart grids, and the continued evolution of LED and OLED technologies promises to further reduce energy consumption in lighting applications.

As we start this new year, the photonics industry is radiating optimism. By embracing these opportunities and fostering collaboration across the global photonics ecosystem, the industry is well positioned to turn breakthroughs into opportunities, lighting the way towards a brighter, more connected, and sustainable future!



Source: Singular Photonics

Shahida Imani

Board of Directors, EPIC
Co-founder and CEO, Singular Photonics

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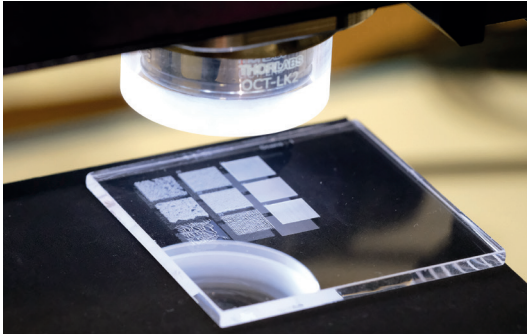
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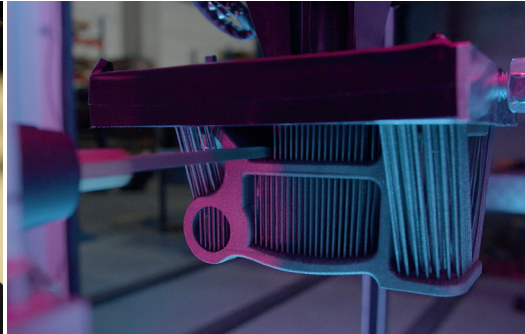
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Glass machining technology with a free surface and thin layers
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COVER STORY
Fiber alignment as part of the production and quality assurance process is required up to two dozen times in the manufacture of photonic components – and is therefore the bottleneck for cost-effective volume production. Active alignment offers the potential to reduce the process time by orders of magnitude.
WILEY

Cover:

Fiber alignment as part of the production and quality assurance process is required up to two dozen times in the manufacture of photonic components – and is therefore the bottleneck for cost-effective volume production. Active alignment offers the potential to reduce the process time by orders of magnitude.

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The manufacturing industry could recover as from 2025

Manufacturing will recover in 2025, but the latest forecast from Interact Analysis has weakened for most regions as the slowdown appears to be more “prolonged” than expected and could extend into next year. This has led to a weaker recovery in 2025 than previously predicted, but output is expected to return to normal by 2026, and the market research specialist does not foresee any major problems for the sector until the end of the decade.

According to the latest Interact Analysis Manufacturing Industry Output (MIO) Tracker, 2024 has proven particularly difficult for many industries, including traditional market sectors such as commercial vehicles, pulp and paper, textiles, and those associated with construction.

An expected strong recovery in the semiconductor sector in 2024 will benefit the economies of the APAC region, such as South Korea, Singapore

and Taiwan, which suffered in 2023 from low demand in a key industry.

In other sectors, many machine OEMs are outperforming their industrial automation component suppliers as demand for both has slowed. The industry appears to be going through a period of destocking, with customers reluctant to invest in machine upgrades while interest rates remain high, and many of the sectors that require machines with drives, motors, and gearmotors are currently in the doldrums. The growth in manufacturing output for 2025 has been revised as the downturn continues.

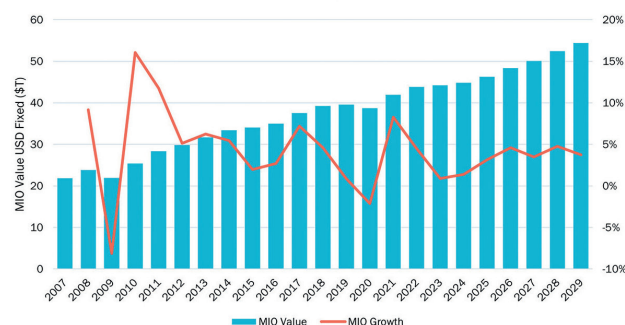
The regions most affected by the downturn are Europe and, to a lesser extent, America; some key regions in the APAC region show stronger signs of continued growth, albeit at a slower rate than in recent years.

In Europe, the automotive sector shows the strongest

CAGR of any sector over the next five years at 4.6 %, despite its recent difficulties, while in APAC the semiconductor and components industry performs best and the transportation sectors in the Americas grow due to infrastructure investment across the region.

Commenting on the latest MIO Tracker, Jack Loughney, Senior Data Analyst at Interact Analysis, says: “The machinery sector is in a difficult position. Demand for machinery is much more volatile than overall demand for manufactured goods, and in every downturn, machinery has underperformed the general economy. As the manufacturing sectors emerge from their own downturns, we expect machinery to rebound strongly in most cases, with equipment such as packaging and semiconductor machinery expected to perform well.”

<https://interactanalysis.com>



The study has predicted the recovery of the manufacturing industry for 2025, but the slowdown is “tough” (Source: Interact Analysis)

China overtakes Germany in the use of robots in industry

The World Robotics 2024 annual report was published by the International Federation of Robotics (IFR). Although Germany installed a record number of 28,355 industrial robots in 2023, it significantly lags behind China in mid-term dynamics: the average annual installation rate (CAGR) between 2018 and 2023 was only 1 %. China surpassed this result twelvefold in the same period.

“China has massively invested in automation technology and ranked third in robot density in 2023, after South Korea and Singapore, ahead of Germany and Japan,” says IFR president Takayuki Ito. “This is particularly remarkable because China only reached the top 10 in the global ranking in 2019. The robot density metric is an important indicator to make the automation of

manufacturing industries internationally comparable by country.”

South Korea is the world leader in manufacturing automation with 1,012 robots per 10,000 employees. The robot density has increased by an average of 5 % annually since 2018. With a leading electronics industry and a strong automotive sector, the Korean economy benefits from two major customer industries for industrial robots.

Singapore follows in second place with 770 robots per 10,000 employees. The electronics industry is by far the largest customer sector for industrial robots, accounting for 75 to 90 %. Due to a relatively small number of employees in the manufacturing industry and the rapidly increasing oper-

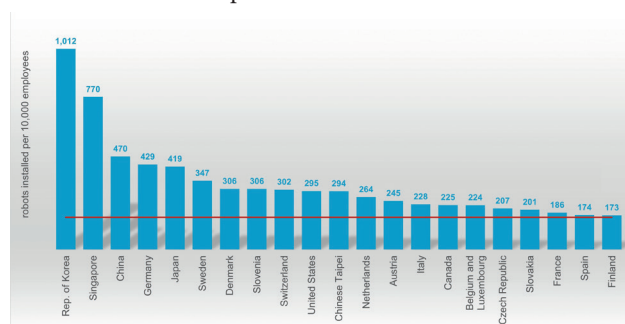
ational stock, Singapore’s robot density is very high.

China ranks third and has more than doubled the ratio of robots per 10,000 factory workers since 2019 (2019: 206; 2023: 470 units). The number of employees in the manufacturing industry is particularly high at around 37 million people.

Germany follows in fourth place with 429 robots per 10,000 employees. The robot density of Europe’s largest economy has increased by an average annual growth rate of 5 % since 2018.

Globally, the average robot density in 2023 reached a new record of 162 units per 10,000 employees – more than double the number seven years ago (2016: 74 units).

www.ifr.org



China has overtaken Germany in the use of robots in industry: the country has moved up to third place in the world rankings with a robot density of 470 units per 10,000 employees (Source: IFR)

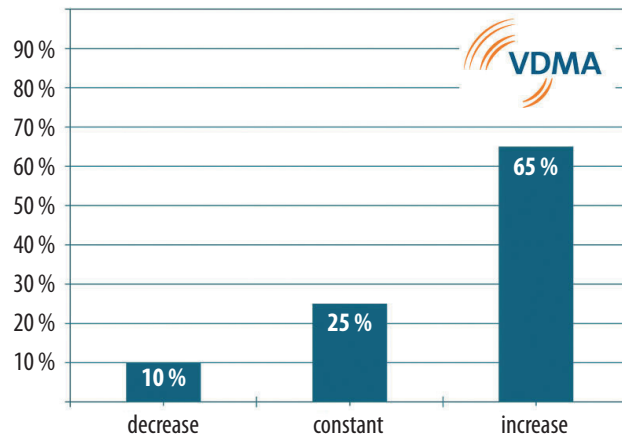
AM industry confident in a tense economic situation

"In the current very difficult market environment across all sectors, our member companies are proving surprisingly robust," explains Markus Heering, managing director of the VDMA's Additive Manufacturing Working Group. "Despite the tense situation, only a third of companies reported declining sales in the fall survey."

There are now also signs of a trend reversal. "Looking ahead to the next 24 months, almost 70 % of respondents expect a return to growth in both the domestic market and the export business," reports Dr Heering. The EU-27 is the most important export region for almost three quarters of member companies, followed by the USA (55 %) and European non-EU countries (31 %). China and other Asian countries, on the other hand, are only among the top sales markets for 9 % of respondents, respectively. "Since the pandemic, business in Asia has clearly lost momentum," says Heering.

The originally high expectations for these markets have not been fulfilled. Instead, competition from China is increasing. More than a third of respondents see their most relevant competitors there. Measured against 65 % who see themselves primarily competing with German AM providers and 44 % who feel competitive pressure primarily from the USA, this is only the third-highest figure. However, there are signs that the AM industry in China is maturing and is now also becoming visible in Europe.

In view of the difficult market environment, the member companies of the VDMA's Additive Manufacturing Working Group are currently holding back on investments. In the first half of the year, only 29 % intend to increase their investments. This figure rises to 45% for the outlook for the year as a whole. "We also interpret this as a sign that companies are generally confident about the future,"



65 % of the surveyed VDMA-AM member companies expect growth in the domestic market (Source: VDMA / WIN)

explains Heering. For 62 % of respondents, this confidence stems from new AM applications and for 40 % from their entry into new markets. More than a fifth of companies also hope that the expansion of their production capacity and increased marketing and R&D activities will provide positive impetus in the current year.

"Our working group brings together a wide variety of players who offer products and services along the additive process and

value chains," says Heering. Despite the heterogeneous composition – providers of AM systems and their suppliers as well as post-processing specialists are represented alongside AM service providers and manufacturers of AM components for in-house use, specialized consultancies, research institutes as well as software and material providers – there is broad agreement on where the AM industry needs to improve.

www.vdma.org

Current industry developments for sensor and measurement technology

According to a survey conducted by the AMA Association for Sensors and Measurement (AMA) among its approximately 450 members, the industry recorded a six percent decline in sales in the second quarter of 2024 compared to the previous quarter. This means that economic development fell short of expectations of plus two percent. Incoming orders fell by one percent, which also reflects a slight decline compared to the first quarter.

This trend is now also affecting the employment situation: 18 percent of AMA members reported short-time working. The survey results continue to show a stable book-to-bill ratio of 1.0. This is con-

sidered an indicator of the medium-term trend in the order situation and is defined as the ratio of incoming orders to sales in the same period.

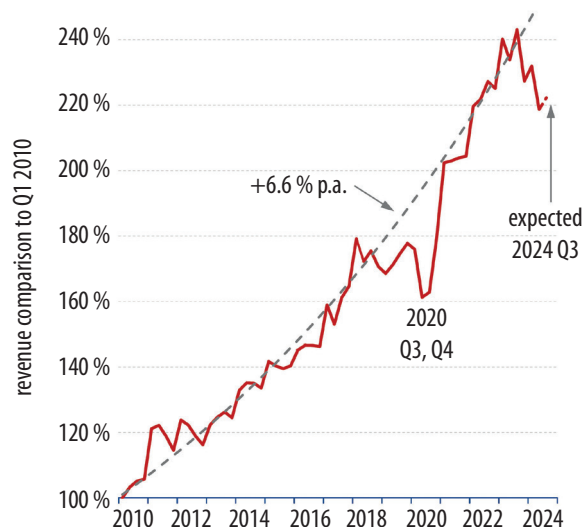
"The development in the second quarter follows the general trend in the manufacturing industry in Germany," explains AMA managing director Thomas Simmons. "The declines in the automotive industry and the difficult situation in energy-intensive sectors have now also affected the sensor and measurement technology industry. Unfortunately, expectations of a recovery in the second quarter were not met."

In view of the economic downturn, the AMA association sees the best approaches

for a positive development in innovation and diversification. In particular, digitization, automation and the expansion of sustain-

able technologies continue to offer member companies in the industry potential for future growth.

www.ama-sensorik.de



Decline in sales and orders in the second quarter of 2024 for sensor and measurement technology (Source: AMA)

PI expands electronics manufacturing

Physik Instrumente (PI) has significantly expanded its electronics manufacturing site in Rosenheim, Germany. The floorspace available was extended by 600 m² to the existing 2,100 m². In addition to optimized logistics, additional workspaces, and new production equipment, a special emphasis was placed on improving ergonomics. The successful expansion was celebrated in the presence of Rosenheim's Lord Mayor Andreas März.

All in all, PI invested 2.2 million euros in the expansion of its electronics manufacturing site. Of this figure, the amount of around one million euros was allocated directly to production and to expanding the floorspace. The company invested more



(l-r) Rosenheim's Mayor Andreas März, PI Site Manager Markus Unterharrer, PI Group CEO Markus Spanner, Carla Kirmis, Agency for Economic Development of the City of Rosenheim, and PI SVP Operations Dr Axel Widenhorn (Source: P. Wehrmuth)

than one million euros in improving the site's infrastructure. In this respect, the main focus was placed on employee needs. Height-adjustable workbenches with integrated lighting in the production area, optimized air-conditioning and ventilation in addition to separat-

ing off areas with high noise levels and high temperatures from other production areas are a few examples of this.

"With the expansion of the site, which has now been completed, we have created the basis for considerable efficiency gains, which are a decisive factor for the growth

we intend to achieve as well as for our successful positioning in the international marketplace," explains Dr Axel Widenhorn, senior vice president operations at PI.

Speaking at the celebrations on completion of the expansion work, Andreas März, Lord Mayor of Rosenheim, emphasized: "We see the importance of providing a good environment for hi-tech companies such as PI. Your investment in this site provides confirmation that we are on the right path in this respect."

In 2025, PI's Rosenheim site will undergo the next stage in its expansion. Further investment funds totaling around 1.7 million euros have been earmarked for this.

www.physikinstrumente.com

NEO expands to Europe with new office in Berlin

Norsk Elektro Optikk (NEO) has established HySpex GmbH in Berlin, Germany, a new office designed to serve as a sales and support hub for customers throughout the EU. This strategic expansion aims to strengthen NEO's European presence and deliver enhanced service to both new and existing clients across the region.

Hallvard Skjerping, CCO of NEO, adds, "We have already witnessed the positive impact of local support for our clients through HySpex Inc, our office in the US. This new office will help us build on that success."

The EU office will be headed by Dr Andreas Eisele and Dr Maximilian Brell, both bringing extensive experience from corporate and academic sectors in hyperspectral imaging. "Having worked with NEO and used HySpex cameras in the past, we are thrilled to join forces and contribute to HySpex's strategic future," says Eisele.

In addition to supporting traditional market segments, HySpex will focus on expanding its role as an OEM provider for industrial suppliers and exploring new opportunities within the space industry. Dr Brell will play a pivotal role in supporting this venture.

www.hyspex.com



Dr Andreas Eisele, Dr Maximilian Brell

"HySpex has a well-established network across Europe, and our EU office will enable us to better reach and support customers on-site," says sales channel manager Lukasz Palukowski.

Ametek acquired Virtek Vision International

The global provider of industrial technology solutions headquartered in Pennsylvania took over the Canadian manufacturer of advanced laser-based projection and inspection systems. Virtek specializes in the development and manufacturing of advanced 3D laser projectors, smart cameras, and quality control inspection systems, powered by AI-driven software and algorithms. Their innovative machine vision solutions provide customers with precise, virtual laser-guided measurement and inspection capabilities to help automate complex assembly processes and improve manufacturing efficiencies across a wide range of aerospace, defense and industrial applications.

Until now, Virtek was owned by private equity investor American Industrial Partners (AIP). "They have been an incredible partner, fueling our growth, driving innovations like our IRIS AI

Inspection Solutions," said Virtek's president and CEO Dietmar Wennemer.

The partnership between Virtek and Creaform enhances technology offerings by combining cutting-edge 3D measurement with laser projection and AI-powered vision solutions.

David Zapico, Ametek chairman and CEO said. "Virtek is an outstanding acquisition and an excellent strategic fit with our Creaform business. Their strong technology capabilities nicely complement Creaform, enabling a broader suite of automated 3D scanning and inspection capabilities supported by advanced software and algorithms."

Virtek is headquartered in Waterloo, Ontario, and has annual sales of approximately 40 million dollars. It will join Ametek as part of its Electronic Instruments Group (EIG).

<https://virtekvision.com>
www.ametek.com

Zeiss and Tesa join forces in advanced holography applications



(r-l) Tesa board member technology Dr Ingrid Sebal, Zeiss Microoptics head Dr Roman Kleindienst with the holographic transparent display for automotive applications

Zeiss and Tesa, international manufacturer of innovative adhesive tapes and self-adhesive product solutions, engaged in a cooperation to strengthen holographic technology. The two companies have been working

together since 2022. The joint projects to date have demonstrated their potential for applications in the mobility and hometech sectors. The partnership combines Zeiss' expertise in optics with Tesa's mate-

rial expertise to develop and bring advanced products to market.

The optical clear adhesives (OCA) from Tesa are of great importance for holographic applications from Zeiss Microoptics. They offer excellent UV-blocking properties, high light transmission and low haze. Other key advantages include excellent temperature, moisture and UV resistance. These properties make the OCA materials ideal for applications in the mobility and hometech sectors for the integration of holographic products.

www.zeiss.com

www.tesa.com

Hamamatsu invests in SuperLight Photonics

SuperLight Photonics, a provider of cutting-edge laser technology, receives a strategic investment of Hamamatsu Ventures to drive long-term synergy in laser innovation. Hamamatsu Ventures, Corporate Venture Capital, is a global VC looking to invest in photonics companies that address the 'sakidori' needs – the future anticipated needs – in society, and more specifically through

the development of disruptive photonics technologies with the potential to redefine industries.

This partnership is poised to accelerate SuperLight Photonics' development of next-generation photonic technologies and strengthen its global market presence. "Our partnership with Hamamatsu Ventures marks a pivotal moment in our growth journey," said Cees Links, CEO of Super-

Light Photonics. "Their support validates the enormous potential of our technologies and strengthens our ability to scale quickly, innovate, and meet the needs of global customers seeking innovative photonic solutions. We are excited to leverage their industry knowledge and network to bring our breakthrough products to new markets."

www.hamamatsu.com

www.superlightphotonics.com

Consolidation plans to strengthen Noblelight operations



UV curing inks with light sources from Noblelight are often used in commercial print shops

Following Excelitas Technologies' acquisition of Noblelight from Heraeus in January 2024, Excelitas is moving swiftly to optimize operations and efficiencies. By the end of 2027, the four production facilities

dedicated to the development and manufacturing of Noblelight products, currently located in the Rhine-Main region of Germany, will be consolidated onto a single expanded site in the same region. Excelitas

expects to invest more than 20 million US dollars in this initiative with the objective of improving operational efficiency.

Excelitas currently produces Noblelight products such as UV LEDs and lamps, analytical light sources, and infrared emitters and systems within four facilities outside of Frankfurt, Germany. The new location will be the center for specialty lamp-based lighting and will include operations, R&D and administration.

www.noblelight.com

www.excelitas.com

ALSO OF INTEREST

Nanosystec becomes part of Addtech

Effective November 5, 2024, the Swedish industrial group acquired the German manufacturer Nanosystec GmbH

Zeiss Microscopy opens Semiconductor Applications Lab

State-of-the-art innovation laboratory in Dresden, Germany, pushes the limits of advanced semiconductor applications

Europe's first R&D center for transparent ceramics

Fraunhofer IKTS opens unique facility at its Hermsdorf site – new equipment covers the entire process chain

New partnership for ultrashort-pulse lasers

LZH and the Ferdinand-Braun-Institute are jointly researching electrically pumped semiconductor disk lasers

Max Planck-New York Center on Non-Equilibrium Quantum Phenomena renewed

The research center will continue its international collaboration for an additional five years with Cornell University as a new partner

Christine Ruffert appointed professor at BTU

The Brandenburgische Technische Universität appointed the former private lecturer and sensor specialist as adjunct professor

Björn Krasemann joins Macnica ATD Europe as VP Sales

In his new role as vice president, he will be responsible for further expanding the company's sales and service activities

New big names join Automotive Chiplet Program

Arm, ASE, BMW, Bosch, Cadence Design Systems, Siemens, SiliconAuto, Synopsys, Tenstorrent, and Valeo gathered at the Automotive Chiplet Forum 2024

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X-Fab and Smart Photonics enable multiterabit transceivers

Source: X-Fab



Rudi De Winter, CEO of X-Fab, and Johan Feenstra, CEO of Smart Photonics

The companies integrate their silicon photonics platform and indium phosphide chiplets using microtransfer printing for heterogeneous integration, enabling new capabilities for datacom and telecom applications.

By co-optimizing silicon photonics, indium phosphide, and microtransfer printing (MTP) technologies to fulfill customer requirements, the collaboration will enable new functionalities and improved system performance while reducing integration costs through relaxed photonics packaging requirements. The MTP technology, licensed from X-Celeprint, enables a broad degree of freedom for the system and product designers by providing flexible integration of various material system chiplets into the product design.

Johan Feenstra, CEO of Smart Photonics, explains: “As the demand for integrated photonics rapidly increases, thanks to the growth of AI and data transfer, our joint solutions will enable much faster data rates while reducing overall power consumption, and therefore the environmental footprint.”

Rudi De Winter, CEO of X-Fab, adds: “Through heterogeneous integration, we are combining the best of the InP and silicon photonics worlds. This will allow our customers to develop innovative solutions address-

ing the societal challenges of our times such as decarbonization. It is also a great opportunity to build a strong European value chain.”

This collaboration builds upon the PhotonixFAB EU funding project, which aims to provide a path to scalable high-volume manufacturing for SOI and SiN silicon photonics, MTP-ready InP chiplets and microtransfer printing of chiplets.

The companies recently signed a memorandum of understanding to formalize their collaboration.

<https://smartphotonics.nl>
www.xfab.com

Lasers4MaaS launched in December, kick-off workshop January 28

Source: EPIC



“Dynamic Beam Shaping for High-Power Laser Beam Welding” event at WMG, January 28th, 2025

The Lasers4MaaS (‘Laser-as-a-Service’) project, funded by the EU, recognizes the strategic importance of digital servitization of laser welding processes and builds

upon the rapidly growing advancement in dynamic laser beam shaping as an “all-in-one” welding tool, allowing many new materials and process optimizations to be enabled from the same laser source. The initiative aims to improve manufacturing processes across industries by integrating advanced laser welding technologies with digital platforms to enable flexible, scalable, and sustainable production solutions.

The project, coordinated by Dr Pasquale Franciosa, head of the laser beam weld-

ing group at WMG, brings together an international consortium of leading academics from the University of Stuttgart IFSW (Germany), TU Wien (Austria), University of Leiden (The Netherlands), and industry experts from Civan Lasers (Israel), United Kingdom Atomic Energy Authority (UK), ECOR International (Italy), IL Sentiero International Campus (Italy), Officine Metallurgiche Cornaglia (Italy), FFT Produktionssysteme (Germany), Futurice (Germany), and the Euro-

pean Photonics Industry Consortium EPIC (France).

To kick off this exciting journey, WMG will host an open-day event on 28 January 2025, focusing on the use of dynamic beam shaping for high-power laser beam welding, one of the core targets of Lasers4MaaS.

The twelve partners from academia and industry aim to transition advanced manufacturing technologies from TRL 4 to 6, ensuring their readiness for real-world applications.

<https://epic-photonics.com>

AMS Osram and Fraunhofer IZM win Deutscher Zukunftspreis for “Digital Light”

German President Frank-Walter Steinmeier honored the winners of the Deutscher Zukunftspreis 2024 at a formal ceremony in Berlin. The award was presented to a team of experts led by

Dr Norwin von Malm and Stefan Grötsch from AMS Osram and Dr Hermann Oppermann from the Fraunhofer Institute for Reliability and Microintegration for the technological implementation of their idea – an LED matrix that turns car headlights into projectors. The technology developed by the team opens up new possibilities for innovative designs thanks to its high-resolution light distribution and its energy efficiency.

As part of their Digital Light project, the research-

ers and their teams have completely rethought intelligent LED technology and established a basic technology that enables numerous new applications, even beyond car headlights. Grötsch, von Malm, and Oppermann have developed a light source that is smaller, lighter, more efficient, more intelligent and more precise in its light output than conventional light sources. The new system will allow car headlights, for example, to illuminate the road ahead precisely and brightly with-

out blinding or endangering oncoming traffic or pedestrians. A conventional low-beam/high-beam combination is not an option here because it must be possible to control the light’s spatial distribution and for the light itself to adapt to the respective situation. To achieve this, the new headlight relies on 25,600 LEDs in a matrix of 320 × 80 points, where each individual LED can be controlled with a digital signal.

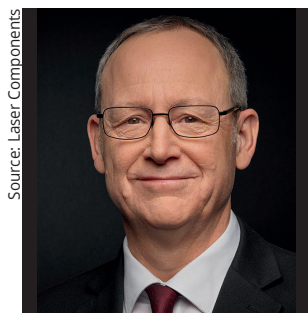
<https://ams-osram.com>
www.izm.fraunhofer.de

Source: AMS Osram



(l-r) Dr Hermann Oppermann, Dr Norwin von Malm, Stefan Grötsch

Leadership change at Laser Components UK



Chris Varney

After 25 years at the helm, Chris Varney is stepping down as managing director of Laser Components UK and will be succeeded by Dan Barlow, who takes on the role of general manager.

Barlow, who joined the company in January as head of sales, has an impressive track record in the photonics sector. He holds an MPhys (Hons) degree and brings nearly two decades of experience across markets such as semiconductors, industrial lasers, fiber optics, and optoelectronics and differ-



Dan Barlow

ent industries including life sciences, aerospace, and defense. Throughout his career, he has held leadership positions with both established industry players and innovative startups.

In his tenure as managing director, Chris Varney has played a pivotal role in the company's transformation from a small operation into a respected name in the industries requiring advanced photonic solutions, such as quantum tech oil and gas sensing, and fire detection.

www.lasercomponents.co.uk

New VP R&D at Instrument Systems

Dr Daniel Winters took over as head of the development department of Instrument Systems in Munich, thereby complementing the management team as vice president research and development under CEO Dr Markus Ehbrecht and managing director Dr Yuta Yamanoi.

Winters holds a PhD in technical physics in the field of semiconductor technology and measurement technology, and contributes more than twenty years of professional experience in the development of optical measurement technology. In his previous positions he was CEO and CTO for Trioptics USA, as well as acting consultant to manufacturers of optical systems and optical measurement technology. His thematic focus is on AR/VR/MR and 3D sensing.

Instrument Systems CEO Dr Markus Ehbrecht said, "With Daniel, a highly expe-



Dr Daniel Winters

rienced manager takes over our motivated development team. Thanks to his expertise in leading optical measurement technologies and their markets, Instrument Systems is once again gaining profile as an innovative solution provider in the latest fields of light measurement technology."

Dr Winters will be responsible for coordinating development activities related to the growing cooperation between the company's international locations.

www.instrumentsystems.com

PhotonicNet appoints Moritz Hinkelmann as Managing Director



Dr Moritz Hinkelmann

The stakeholders of the regional competence network PhotonicNet have appointed Dr Moritz Hinkelmann as the new managing director. He succeeds Dr Thomas Fahlbusch, who is devoting himself to other professional challenges.

Philipp Becker, shareholder spokesman and managing director of Vision Lasertechnik said, "We would like to thank Dr Fahlbusch for his many years of successful work. In the 15 years of his leadership,

the network has achieved important milestones and made valuable offers to its members. We wish him all the best for the future and every success in his future endeavors."

Dr Hinkelmann has extensive experience and expertise in photonic technologies. After studying optical technology, he completed his doctorate at Leibniz Universität Hannover. He has been working at the Laser Zentrum Hannover since 2016, where he has headed the optical systems group in the laser development department since 2020.

From 2021 to June 2024, Dr Hinkelmann was managing director of the Wissenschaftliche Gesellschaft Lasertechnik und Photonik eV (WLT).

<https://photonicnet.de>

IBM's Heike Riel to head the DPG as 2026 – 2028 president

At its last meeting, the German Physical Society DPG's board of directors elected industrial physicist Heike Riel as the future president of the world's largest physics society.

The election of a new executive board takes place every two years. In April 2026, Riel will take over from incumbent president Klaus Richter, who cannot be re-elected according to the articles of association and continues as vice president.

Riel initially completed an apprenticeship as a carpenter before studying physics at FAU Erlangen-Nuremberg. After an internship at the Hewlett-Packard Research Laboratory in Palo Alto, she joined IBM Research in Zurich as a doctoral student in 1998. She carried out her doctoral thesis on the optimization of multi-



Dr Heike Riel

layer OLEDs in collaboration with IBM Research at the University of Bayreuth and then became a research associate at IBM Research, and in 2008 became head of the research group for material integration and nanoscale devices. One of the highlights was the development of quantum devices for use in quantum computers. In 2010, she also obtained an MBA from Henley Business School.

www.dpg-physik.de

Norbert Hanke appointed interim president and CEO of Hexagon



Norbert Hanke

Hexagon's board of directors and Paolo Guglielmini have mutually agreed that Paolo steps down from his position as president and CEO. The board sees a new leadership approach as essential to steer the company through its next phase.

On November 11, the board of directors appointed Norbert Hanke as interim president and chief executive officer of Hexagon

AB with immediate effect. Hanke joined Hexagon in 2001, most recently serving as Hexagon's chief operating officer and prior to that as Hexagon's Manufacturing Intelligence division president for more than ten years.

"The board of directors is starting the process of recruiting a new CEO to accelerate our growth and to capture the opportunities we see in the market. In the meantime, day to day operations will be overseen by Norbert, with the full support of myself and the board. I would like to thank Paolo for his 14-year tenure with Hexagon and his last two years as CEO," said Ola Rollén, chairman of the Hexagon's board in a webcast and telephone conference.

<https://hexagon.com>

Evosys expands its management team

Marie Schafnitzl as head of finance and Oliver Brandmayer as technical director joined the company's management team on October 1, 2024. With this decision, the company is responding to the expanding business area and the increasing number of employees. The company is strengthening its strategic focus, intensifying its market orientation and laying the foundations for continuous growth.

Schafnitzl has experience and extensive knowledge in the areas of controlling, accounting, information technology, marketing and communication.



Marie Schafnitzl

Oliver Brandmayer has been an integral part of Evosys as head of development and project management since the company was founded, and Evosys is bringing another experienced manager to the board. Mr Brandmayer is responsible for product safety and will assume responsibility for engineering and project management. Here he will contribute his extensive know-how, planning skills and employee development to expand the company's market position as an innovation leader in the long term.

www.evsys-laser.com



Oliver Brandmayer

Scintil Photonics names Matt Crowley as CEO



Matt Crowley

The founder and previous CEO of the provider of advanced photonic integrated circuits, Sylvie Menezo, continues heading technology developments and customer partnerships as managing director. Matt Crowley will be the new CEO, responsible also for the establishment of a US subsidiary to support the expanding customer base in data centers, machine learning, and AI.

Crowley joins Scintil following his recent role as senior director business development at Qualcomm, where he arrived after lead-

ing Vesper Technologies, a MEMS technology company, through its acquisition by Qualcomm.

This evolution in strategic leadership and US presence come as Scintil's LEAF Light product gains traction in AI computing applications, where it serves as a critical remote light source for GPU interconnects in AI data centers. This is the first light source of its kind able to provide a single chip solution with high power output, high efficiency, small form factor and tightly controlled channel spacing required for extremely high data rate communications.

Created in 2018, Scintil and its team of thirty now comprises a US subsidiary, in addition to the two sites located in France (headquarters) and Canada. This new US footprint reinforces the company's capabilities to address local needs as well as serve customers globally.

www.scintil-photonics.com

Trade association with new chairman

Dr Dietmar Ley, CEO of Basler AG, has been elected as the new chairman of the VDMA Robotics + Automation Association. Ley has been active in various committees and roles at the VDMA for around twenty years and was most recently deputy chairman of the association. He takes over the role from Frank Konrad of CEO Hahn Automation Group, whose three-year term as chairman has ended and who now occupies the post of deputy chairman.

Ley emphasizes: "I look forward to continuing the work of the trade association as a strong voice for robotics and automation in Europe together with my colleagues. In the current very dynamic and geopolitically uncertain times, it is crucial that



Dietmar Ley

we promote our technology and innovation leadership in this field."

The association represents more than 400 European suppliers of components and systems in robotics, integrated assembly solutions and machine vision. It supports robotics and automation through a wide range of activities and services.

www.baslerweb.com
www.vdma.org

New security module for improved UV detection

Manufacturer: Hamamatsu Photonics

Product: The C16956-02 is designed for ultraviolet (UV) detection, expanding the existing UVTRON series. It improves efficiency and reliability in applications such as flame sensing and electric discharge identification.

Features: The UVTRON module features a driver circuit and signal processing capabilities to reduce background noise, enhancing the accuracy of UV detection. The light-receiving section of the C16956-02 has a G1 female thread for easy integration into systems when connected to a DC voltage supply. This facilitates a quick setup and allows users to



detect UV signals without complex configurations. The module also includes an internal UV-LED to check its operational status, reflecting Hamamatsu Photonics'

focus on creating user-friendly products.

Applications: UV detection plays a crucial role in ensuring safety across numerous sectors and various industrial settings. With the launch of the UVTRON module, Hamamatsu aims to set a new standard for reliability and ease of use in UV detection technology.

Hamamatsu Photonics Europe

Arzbergerstr. 10
82211 Herrsching am Ammersee
Germany
Web: www.hamamatsu.com
Meet us at BiOS, Booth 8411
Photonics West, Booth 1127

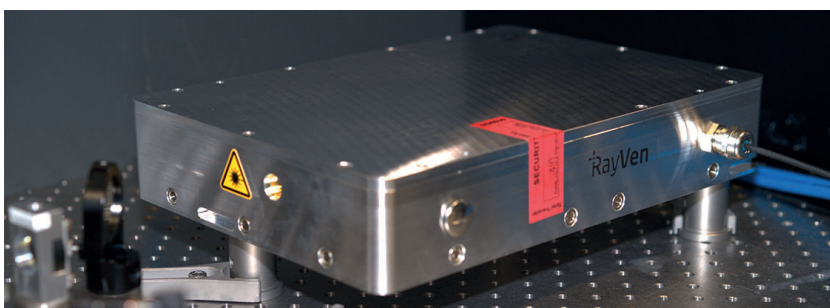
2.1 μm ultrafast lasers

Manufacturer: RayVen

Product: RayVen offers ultrafast lasers that operate exclusively at two microns (short-wavelength infrared range, SWIR).

Features: Designed with femtosecond and picosecond pulse durations, these lasers deliver exceptional stability in a compact design, with low noise performance, and unparalleled peak power for industrial-grade lasers.

Applications: RayVen-S provides 1 W of average power at a 50 – 70 MHz repetition rate, with 120 fs pulse durations across wavelengths from 2,090 nm to 2,120 nm. Compact and robust, it is ideal for research and industrial applications that require high precision. RayVen-L is tailored for high-energy tasks, delivering 10 W of average power and up to 1 mJ of pulse energy with 800 fs pulse durations, excelling in applications that demand



high peak power. Known for their outstanding performance in material processing, scientific research, gas sensing, and more, RayVen lasers are increasingly sought after by semiconductor and microfluidics suppliers.

Ruhr University Bochum

RayVen spin-off of PULS –
Photonics and Ultrafast Laser Science
Universitätsstr. 150
44801 Bochum, Germany
phone: +49 234 32 23162
e-mail: info@rayvenlaser.com
Web: <https://rayvenlaser.com>
Meet us at Photonic West 2025
German Pavilion, Booth 4205

Industrial-scale micropart production service

Manufacturer: UpNano

Service: A new chapter in high precision two-photon polymerization (2PP) 3D printing began with the launch of their NanoPro service during the Formnext trade show. A newly developed printer model acts as the powerful engine that runs the new service, offering serial production of microparts with nanometer-resolution.

Features: The technical capabilities of the patented NanoPro VT printing system enable a performance of 32 Megavoxels (million volume pixels) per second compared to projection-based technol-

ogies (DLP) at only two Megavoxels in about three to ten seconds. Depending on the configuration, this translates into a throughput of several thousand cubic millimeters per hour, many factors higher than any other 2PP technology currently on the market.

Applications: The miniaturization of production parts has often reached the limits of existing technologies such as DLP, μSLA , SLA, MIM or FDM. Designs are becoming increasingly intricate and complex, while production tolerances are becoming more stringent. In addition, the global economy is driving fierce

competition, making economy of scale through high-volume production even more necessary than ever. On top of its technical competencies, UpNano is ISO 9001 and 14001 certified, ensuring that any service offered fulfils the latest industry and environmental standards.

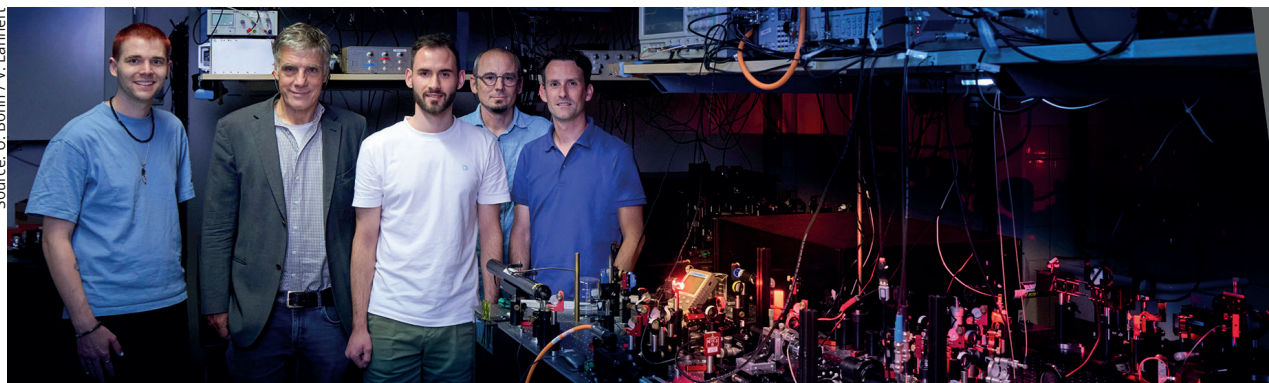
UpNano

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1030 Vienna
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Web: www.upnano.com

A superphoton for tap-proof communication

Bose-Einstein condensate improves the communication between many participants

Source: U. Bonn / V. Lannert



The University of Bonn team: Niels Wolf, Martin Weitz, Andreas Redmann, Frank Vewinger, and Julian Schmitt

Thousands of light particles can merge into a type of super photon under certain conditions. Researchers at the University of Bonn have now been able to use tiny nanomolds to influence the design of such a Bose-Einstein condensate. This enables them to shape the speck of light into a simple lattice structure consisting of four points of light arranged in quadratic form. Such structures might be used in the future to make the exchange of information between multiple participants tap-proof.

When a large number of light particles are cooled to a very low temperature and simultaneously confined in a compact space, they suddenly become indistinguishable and behave like a single super photon. This Bose-Einstein condensate resembles a blurry speck of light. “However, we have now managed to imprint a simple lattice structure on the condensate,” says team member Andreas Redmann. The researchers create superphotons by filling a tiny

container with a dye solution. The side walls of the container are reflective. If the dye molecules are excited with a laser, they produce photons that bounce back and forth between the reflective surfaces. These light particles start off relatively warm. However, they repeatedly collide with the dye molecules as they move between the reflective surfaces and cool down until they finally condense to form a superphoton.

“The reflective surfaces are normally perfectly smooth,” explains Redmann. “We decided to deliberately add small indents to them, which figuratively speaking provide more space for the light to collect in them.” This effectively imprints a structure onto the condensate – almost like when you press a mold with one closed side downwards into a sandbox: if you lift it up again, you can still see the imprint of the mold in the sand. “In this way, we have managed to create four regions where the condensate prefers to stay,” says Redmann. It is as if you were to divide

a bowl of water between four cups arranged in quadratic form. In contrast to water, however, the superphoton will not necessarily split into four smaller portions. If the cups are positioned closely enough together so that the light particles can pass quantum mechanically back and forth between them, it remains as one single condensate.

This property could be used, for example, to create quantum entanglement. If the light in one cup changes its state, it will also impact the light in the other cups. This quantum physical correlation between the photons is a basic requirement for making the exchange of information – such as discussions or secret transactions – between several participants tap-proof. (Source: U Bonn)

A. Redmann et al.: Bose-Einstein Condensation of Photons in a Four-Site Quantum Ring, *Phys. Rev. Lett.* 133, 093602 (2024); DOI: 10.1103/PhysRevLett.133.093602

www.qfl.uni-bonn.de

Pushing the limits of conventional lasers

A project starts for a new type of light source for extremely fast laser pulses

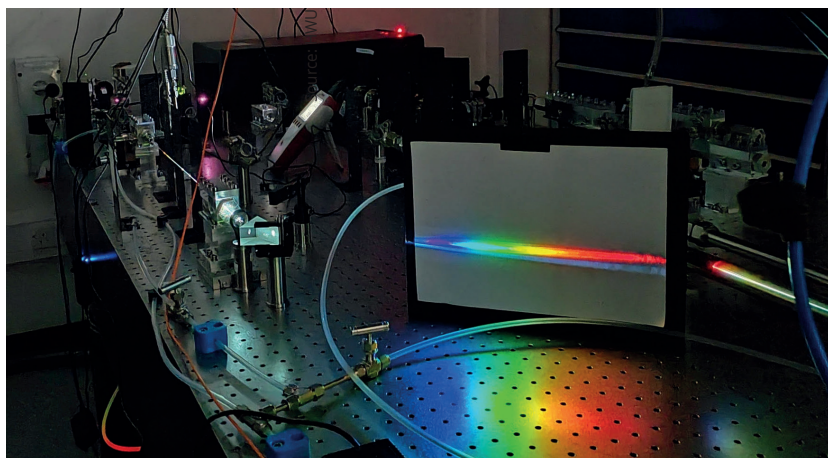
Christian Brahms from Heriot-Watt University is to receive over two million pounds in European funding to fill in the blind spots of Nobel Prize-winning technology. He will spend the next five years building a new type of light source for extremely fast laser pulses. The aim is to capture nature's fastest processes as they happen, at the rate of an attosecond. This could allow us to see some of the fastest processes in nature, like how plants absorb sunlight.

The project will address a key shortcoming of attosecond technology so far: it cannot see everything. Christian Brahms said: “Many of the most important breakthroughs in the history of science have been enabled by observing nature at scales far beyond the limits of human perception. That is exactly what we will be working on – pushing far beyond the limits of conventional laser sources to bring fundamental science into focus.”

Brahms will be working to create a new kind of laser light that mimics natural sunlight but in extremely short flashes. He said: “Current technology, like that reported by the 2023 Nobel Prize winners, can create extremely short pulses of light at ultraviolet or X-ray wavelengths. This incredible advance allows us to take ‘freeze-frame’ images of some of the fastest microscopic processes in molecules and materials. But it is limited. In nature,

these processes involve sunlight, not the wavelengths used in laboratory experiments. My aim is to create extremely short duration laser pulses, similar to conventional attosecond science sources, but at ultraviolet and visible wavelengths.”

This will fill in attosecond technology’s blind spots and directly relate our knowledge of ultrafast processes to other areas, like photochemistry or materials science. The project will create five new jobs at Heriot-Watt University: Brahms will be recruiting three PhD students and two postdoctoral research associates to help design and build the laser light source. Brahms’ project is one of fifty in the UK to receive the European Research Council Starting Grant in 2024. Brahms said:



Scientists at Heriot-Watt University are building a new type of light source for extremely fast laser pulses

“The ERC grants had an application success rate of just 14 % – we are officially among the most dynamic and

exciting research projects in Europe.”
(Source: HWU)

<http://lupo-lab.com>

Record-breaking laser pulses

Producing the strongest ultrashort pulses to date for precision measurements or materials processing

A team of researchers at ETH Zurich led by Ursula Keller have now set a new record for laser pulses: at 550 watts of average power they surpass the previous maximum by more than fifty percent, which makes them the strongest pulses ever created by a laser oscillator. At the same time, they are extremely short – they last less than a picosecond and exit the laser in a regular sequence at a high rate of five million pulses per second. The short pulses reach peak powers of a hundred megawatts.

“The combination of even higher power and pulse rates of 5.5 megahertz, which we have now achieved, is based on two innovations”, explains Moritz Seidel, a PhD student in Keller’s laboratory. For one thing, he and his colleagues used a special arrangement of mirrors that send the light inside the laser through the disk several times before it leaves the laser through an outcoupling mirror. “This arrangement allows us to amplify the light considerably without the laser becoming unstable”, says Seidel.

The second innovation regards the centerpiece of the pulsed laser: a special mirror made of semiconductor material, which was invented by Keller thirty years ago and goes by the memorable abbreviation SESAM (semiconductor saturable absorber mirror). Unlike normal mirrors, the reflectivity of a SESAM depends on the strength of the

light hitting it. Using the SESAM, the researchers coax their laser into sending out short pulses rather than a continuous beam. Pulses have a higher intensity because the light energy is concentrated into a shorter period of time.

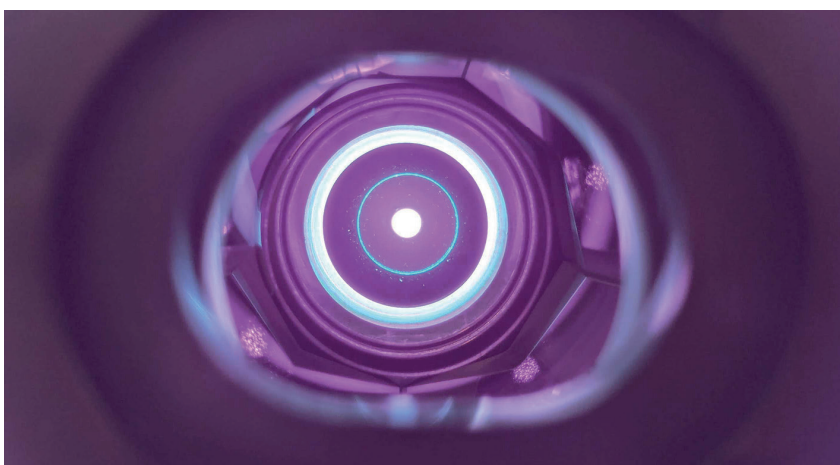
Ursula Keller is also thrilled by these results and emphasizes: “We now also expect to be able to shorten these pulses very efficiently to the regime of a few cycles, which is very important for creating attosecond pulses.” According to Keller, the fast and strong pulses made possible by the new laser could also see applications in new frequency combs in the ultraviolet to X-ray regime, which could lead to even more precise clocks. “A dream would be to show, one day, that the natural

constants are not constant after all”, says Keller.

Also, terahertz radiation, which has a much longer wavelength than visible or infrared light, can be created with the laser and then used to test materials, for example. “All in all, one can say that with our pulsed lasers we have shown that laser oscillators are a good alternative to amplifier-based laser systems and that they enable new and better measurement”, Keller summarizes. (Source: ETHZ)

M. Seidel et al.: Ultrafast 550-W average-power thin-disk laser oscillator, *Optica* 11, 1368 (2024); DOI: 10.1364/optica.529185

<https://ulp.ethz.ch>

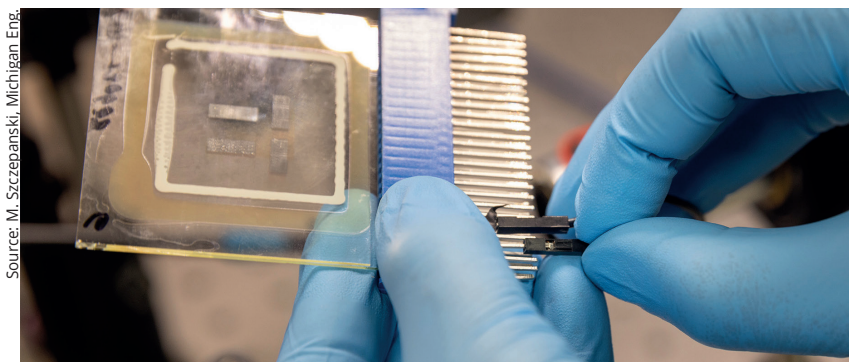


A peek inside the record-breaking laser. The image shows the round amplifier disk, through which the laser beam passes several times (bright spot at the center)

Source: Moritz Seidel / ETH Zurich

An OLED for compact night vision

A new device amplifies and converts near infrared light into visible light



Source: M. Szczepanski, Michigan Eng.

Researcher Raju Lampane positions an OLED that leverages positive feedback to amplify the conversion of NIR light into visible light in front of a microscope imaging system

A new type of OLED could replace bulky night vision goggles with light-weight glasses, making them cheaper and more practical for prolonged use, according to University of Michigan researchers. A memory effect in the OLEDs could also lead to computer vision systems that both sense and interpret incoming light signals and images.

The newly developed OLED device also converts NIR into visible light and amplifies it more than a hundred times like traditional devices, but without the weight, high voltage and cumbersome vacuum layer required for current image intensifiers. The researchers say much higher amplification is possible by optimizing the design of the device.

“One of the most attractive features of this new approach is that it ampli-

fies light within a thin film stack that is less than a micron thick,” said lab leader Chris Giebink. Because the device operates at a much lower voltage than a traditional image intensifier, it opens the door to significantly reducing power consumption and thereby extending battery life. The device works by integrating a photon-absorbing layer, which converts infrared light into electrons, and a five-layer stack of OLEDs, where those electrons are converted into visible light photons. Ideally, five photons are produced for each electron that passes through the OLED stack.

Some of these photons are emitted out to the user’s eye, but others are reabsorbed back in the photon-absorbing layer, producing still more electrons that move through the OLED in a pos-

itive feedback cycle. This chain reaction greatly amplifies the amount of output light that results for a given amount of input light. Previous OLEDs were able to convert near infrared light to visible light, but there was no gain, meaning one input photon yielded one output photon. The device also exhibits a sort of memory behavior that could have applications in computer vision. Its light output at a given moment depends on the intensity and duration of past input illumination.

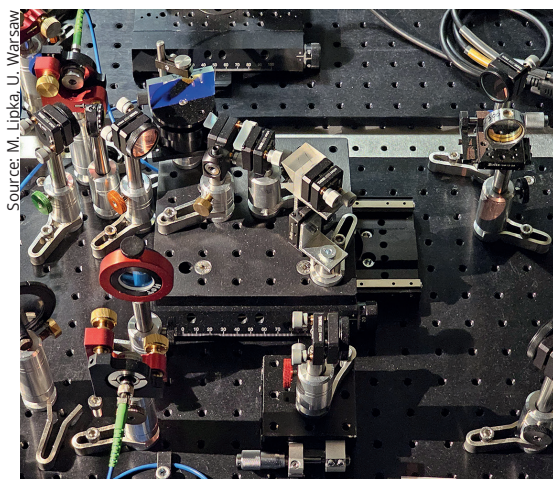
The ability to remember past inputs could make these OLEDs a good candidate for the type of neuron-like connections that enable an input image to be interpreted and classified without having to process the data in a separate computing unit. The researchers fabricated the device using ‘off the shelf’ materials and methods that are already widely used in OLED manufacturing, which should improve both cost effectiveness and scalability for future applications of the technology. (Source: U Michigan)

R. Lampane et al.: Positive-feedback organic light-emitting diodes and upconverters, *Nat. Photon.*, online 13 September 2024; DOI: 10.1038/s41566-024-01520-0

<https://ece.engin.umich.edu>

A quantum-inspired super-resolving spectrometer

New device improves resolution more than two-fold compared to standard approaches



Source: M. Lipka, U. Warsaw

Frequency lens using multiple diffraction on a diffraction grating. The light pulse is transformed in a frequency analogous to the light beam passing through the real lens

Two researchers at the University of Warsaw developed a quantum-inspired superresolving spectrometer for short pulses of light. The device offers a more than two-fold improvement in resolution compared to standard approaches. In the future, it can be miniaturized on a photonic chip and applied in optical and quantum networks as well as in spectroscopic studies of matter.

Progress in quantum information science has allowed us to understand that traditional direct imaging or spectroscopy discards part of the information that is carried in the phase of the complex electromagnetic field of light. The quantum-inspired superresolution techniques transform the complex elec-

tromagnetic field before it is detected to optimally use this latent information. The working principle of the device – superresolution of ultrafast pulses via spectral inversion (SUSI) – is very similar to the quantum-inspired superresolution methods in imaging. The greatest challenge was how to translate these ideas to the realm of time and frequency.

In superresolved quantum imaging, the light coming from the object is split into two arms of an interferometer. One arm contains a device that inverts (flips) the image. Then the inverted part interferes with the original one. Now, for instance if there is only one tiny emitter perfectly aligned with

the inversion axis, its inverted image will be identical to the original one. In this case we would see no photons in one of the interferometer ports. However, as soon as the emitter is moved, its inverted image will become different from the original and photons will appear in that port. Their number is a very good indicator of how much the emitter was moved.

Taking this example a step further, imagine two emitters that are separated symmetrically around the inversion axis. Each emitter will contribute to the counted photons in the same way, hence one has measured the separation between two emitters. As with every

measurement, it has a limited precision, but it turns out that this precision can be significantly better compared to just directly imaging the emitters with a camera.

In the realm of time and frequency these ideas still hold. Having pulses of light instead of tiny emitters, these pulses appear at the same time but each has a slightly different color, because they come from different optical channels or different spectroscopic lines. In a standard approach, instead of directly looking with a camera, one would first use a dispersive device such as a diffraction grating or a prism that would send different frequencies to different

positions on the camera sensor. With two closely separated pulses, these frequency distributions will mostly overlap, limiting the precision with which the separation can be measured. SUSI can improve this precision. All elements used in the SUSI interferometer can already be implemented on a photonic chip, making SUSI very applicable and integrable in superspectrometers or devices for optical networks. (Source: U. Warsaw)

M. Lipka & M. Parniak: Super-resolution of ultrafast pulses via spectral inversion, *Optica* 11, 1226 (2024); DOI: 10.1364/optica.522555

<https://qot.cent.uw.edu.pl>

A new method for photonic in-memory computing

Novel approach to combine non-volatility, multibit storage, high switching speed, and low switching energy

A team of researchers from the University of Pittsburgh Swanson School of Engineering, the University of California Santa Barbara, the University of Cagliari, and the Tokyo Institute of Technology, has developed a new method for photonic in-memory computing that could make optical computing a reality in the near future.

Until now, researchers have been limited in developing photonic memory for AI processing – gaining one important attribute like speed while sacrificing another like energy usage. Now, the team demonstrates a unique solution that addresses current limitations of optical memory that have yet to combine non-volatility, multibit storage, high switching speed, low switching energy, and high endurance in a single platform.

“The materials we use in developing these cells have been available for decades. However, they have primarily been used for static optical applications, such as on-chip isolators rather than a platform for high performance photonic memory,” Nathan Youngblood from the University of Pitts-

burgh explained. “This discovery is a key enabling technology toward a faster, more efficient, and more scalable optical computing architecture that can be directly programmed with CMOS circuitry – which means it can be integrated into today’s computer technology. Additionally, our technology showed three orders of magnitude better endurance than other non-volatile approaches, with 2.4 billion switching cycles and nanosecond speeds.”

The scientists propose a resonance-based photonic architecture that leverages the nonreciprocal phase shift in magneto-optical materials to implement photonic in-memory computing. By using magneto-optic memory cells comprised of heterogeneously integrated cerium-substituted yttrium iron garnet (Ce:YIG) on silicon micro-ring resonators, the cells cause light to propagate bidirectionally. This provides an additional level of control not possible in more conventional non-magnetic materials.”

The team is now working to scale up from a single memory cell to a large-



Source: B. Long, UCSB

A concept image of the group's photonic in-memory computing

scale memory array that can support even more data for computing applications. (Source: U. Pittsburgh)

P. Pintus et al.: Integrated non-reciprocal magneto-optics with ultra-high endurance for photonic in-memory computing, *Nat. Photon.*, online 23 October 2024; DOI: 10.1038/s41566-024-01549-1

<https://pitt-photonics.github.io>



Optical Filters

For applications in research and industry

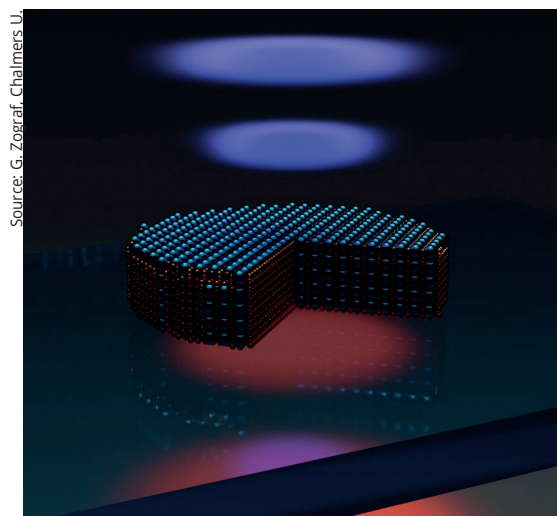
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Unique nanodisk pushing photonic research forward

A new tool for enhancing the entire spectrum of optical second-order nonlinear processes



Schematic of the optical experiment: a near-infrared laser excites the nanodisk fabricated from the 3R-molybdenum disulfide flake

Researchers at the department of physics at Chalmers University of Technology have succeeded in combining two major research fields – nonlinear and high-index nanophotonics – in a single disk-like nanoobject.

“The disk-like structure is much smaller than the wavelength of light, yet it is a very efficient light frequency converter. It is also 10,000 times, or maybe even higher, more efficient than the unstructured material of the same kind, proving that nano structuring is the way to boost efficiency,” says Georgii Zograf. Somewhat simplified, it is a combination of material and optical resonances with the ability to convert light frequency through a crystal’s non-linearity that the researchers have combined in the nanodisk.

The atomically thin molybdenum disulfide (TMD) has a high refractive index – 4.5 in the visible optical range. Furthermore, the material has the advantage of being transferable onto any substrate without the need to match the atomic lattice with the underlying material. The nanostructure is also very efficient in localizing electromagnetic field and generating doubled frequency light out of it, a second-harmonic generation. This nanodisk combines extreme non-

linearity with a high refractive index in a single, compact structure.

“It really is a milestone, particularly due to the disk’s extremely small size. Second harmonic generation and other non-linearities are used in lasers every day, but the platforms that utilize them are typically on the centimeter scale. In contrast, the scale of our object is about fifty nanometers, that is about a 100,000 times thinner structure,” says research leader Timur Shegai.

The researchers believe that the nanodisk’s work will push photonics research forward. In the long term, TMD’s incredibly compact dimensions, combined with their unique properties, could potentially be used in advanced optical and photonic applications.

G. Zograf et al.: Combining ultrahigh index with exceptional nonlinearity in resonant transition metal dichalcogenide nanodisks, *Nat. Phot.* 18, 751 (2024); DOI: 10.1038/s41566-024-01444-9

www.chalmers.se

Boosting the power of ultrasmall spectrometers

Very efficient device combines multimode interference waveguides with machine learning analysis

University of California Santa Cruz researchers are designing new ways to make spectrometers that are ultrasmall but still very powerful, to be used for anything from detecting disease to observing stars in distant galaxies. Their inexpensive production cost makes them more accessible and customizable for specific applications. The team of researchers is led by an interdisciplinary

collaboration between Holger Schmidt and Kevin Bundy.

The researchers demonstrate an extremely high-performance spectrometer that can measure light with a 0.05 nm wavelength resolution. That is the same resolution that can be achieved on a device a thousand times bigger. Their device is a miniature, high-powered waveguide that is mounted on a chip and used to guide light into a specific pattern, depending on its color.

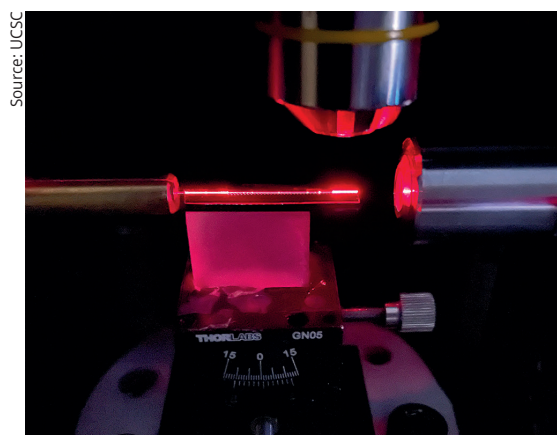
Information from the chip is fed into a machine-learning algorithm that reads the patterns created by different wavelengths of light in order to reconstruct the image with extremely high accuracy and precision – an approach of reconstructive spectrometry. This technique produces accurate results because the machine-learning algorithms do not require highly precise input to be able to distinguish the light patterns, and can constantly improve upon their own performance and optimize themselves to the hardware.

Because of this, the researchers can make the chips with relatively easy and inexpensive fabrication techniques, in a process that takes hours rather than weeks. The lightweight, compact chips for this project were designed at UCSC, and fabricated and optimized at Brigham Young University in partnership with Schmidt’s longtime collaborator Aaron Hawkins and his undergraduate students.

The researchers envision that this technology can be used for a wide range of applications, though their preliminary focus is to create powerful instruments for astronomy research. Because their devices are relatively inexpensive, astronomers could specialize them to their specific research interests, which is practically impossible on much larger instruments. (Source: UCSC)

M. N. Amin et al.: Multi-mode interference waveguide chip-scale spectrometer, *APL Photon.* 9, 100802 (2024); DOI: 10.1063/5.0222100

<https://photon.soe.ucsc.edu>



Red laser light is coupled into a spectrometer chip with an optical fiber from the left

Innovative monochromator optimizes process control

Patented device measures the optoelectronic properties of semiconductor materials over a broad spectral range

The spectrally dependent photoelectric characterization of semiconductor materials requires light sources whose photon energy can be continuously varied. Such light sources consist of a lamp, which emits light over a broad spectral range, and a monochromator, which filters out light in narrow spectral ranges. Until now, only diffraction grating monochromators have been used commercially, requiring up to five different diffraction gratings to cover a wide spectral range.

strongly by more than eight orders of magnitude, which makes the monochromator particularly suitable for the photoelectric characterization of defects in semiconductors. Due to its high intensity even in the deep ultraviolet, the monochromator is also excellently suited for the characterization of semiconductor materials with wide or ultrawide band gaps, such as silicon carbide and gallium oxide for high-performance electronics, diamond for IT technologies and gallium nitride for



Source: T. Dittrich, HZB

The patented monochromator consists of quartz glass optics with two prisms and a few lenses

At the HZB in Berlin, a team led by Thomas Dittrich, in collaboration with the Hereon research center near Hamburg, has now developed a mirrorless double prism monochromator based on fused silica. Since fused silica is transparent in a spectral range from about 0.4 to over 7.3 eV, light can be spectrally dispersed over this range with just one fused silica prism. A first prototype was realized together with Freiberg Instruments. The novel, now patented, monochromator consists of a fused silica optics with two prisms and some lenses, where in addition to the dispersion-dependent rotation of the prisms, a precise adjustment of the lenses is done via stepper motors. A laser-driven xenon lamp provides high light intensities even in the deep ultraviolet.

The new monochromator makes it possible to determine the optoelectronic and optical properties of semiconductor materials in a single continuous measurement over a very wide spectral range from the near infrared to the deep ultraviolet. An additional advantage: stray light is suppressed very

optoelectronically. With the new compact monochromator, for example, it is now possible for the first time to characterize defect states across almost the entire band gap of aluminum nitride in just a few minutes.

The new monochromator improves the characterization of electronic properties, especially of wide and ultrawide bandgap semiconductors. This innovation is therefore not only relevant for the research and development of new materials, but can also be used in process development and industrial process control. In collaboration with Freiberg Instruments, the HZB researchers have already built a prototype. Freiberg Instruments is introducing this compact monochromator into the market now. "There is a lot of interest and demand," says Dittrich. (Source: HZB)

T. Dittrich et al.: Mirrorless fused silica based double-prism monochromator for continuous measurements from the near infrared to deep ultraviolet, *Appl. Opt.* 63, 6880 (2024); DOI: 10.1364/ao.529366

www.helmholtz-berlin.de
www.freiberginstruments.com

ALSO OF INTEREST

First demonstration of a dual-media NV diamond laser system

New approach to measure extremely low magnetic fields in the femtoTesla to picoTesla range

Tiny hurricanes of light

Physicists at Aalto University, Finland, unlock transformative new way to transmit information over laser light

Controlling light with photonic time crystals

Discovery could dramatically enhance technologies like lasers, sensor, and optical computing in the near future

Measuring defects to better understand quantum systems

New method from University of Chicago researchers based on the intrinsic correlation between the charge and spin states of defect centers

Germany's first photonic quantum computer performing calculations

Researchers at Paderborn University highlight their pioneering role in the development of light-based quantum technologies

Unidirectional imaging improves visual information processing

A new optical technology from the UCLA's Ozcan Research Lab could significantly enhance communication systems

A keener eye for the invisible

Empa researchers in Switzerland invent new type of detector for infrared radiation made from quantum dots

Supermicroscope shows nanoscale biological process for the first time

New device at Radboud University Medical Center provides more insight into arterial calcification

Light emission patterns from 3D-printed nanowires

Korean researchers see possible applications in optical communication, sensing, and imaging, where the directionality of the emissions is crucial

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University of Stuttgart
Institute of Applied Optics

INVITATION AND PROGRAM CALL

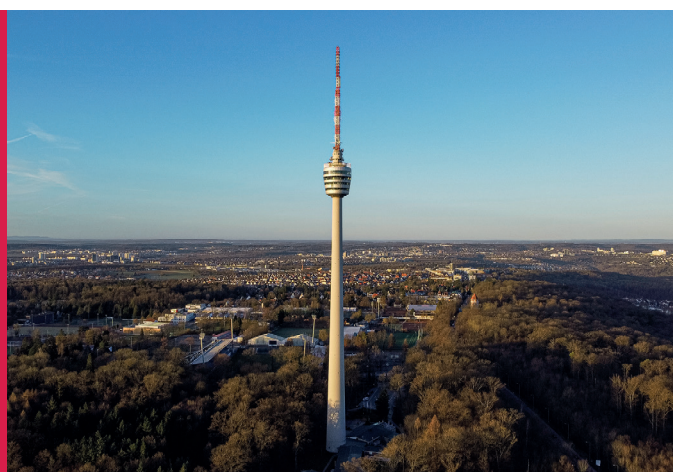
The German Society for Applied Optics (DGaO) invites you to the

126TH ANNUAL MEETING OF THE DGaO

10 – 14 June 2025 in Stuttgart, Germany
at the University of Stuttgart

Contributions in the area of applied optics are welcome, with a focus on:

- Optical metrology and measurement systems
- Optical design and opto-mechanical system design
- Photonic sensors and systems for industry and life sciences
- Optics in production (laser material processing, additive manufacturing)
- Miniaturized optical systems for industrial applications: design, realization, testing
- Optics for automotive applications
- Ultraprecision- and nanometrology



Source: Stuttgart-Marketing GmbH

Call for Abstracts

We invite you to submit oral presentations (12 min plus 3 min discussion) and posters from the list of topics above or from the general field of applied optics. Please use the online system at www.dgao.de. The abstracts should not exceed 1,200 characters (including blank characters). Conference language is German, English contributions are welcome.

Program Committee

Prof Dr Christian Faber, Hochschule Landshut; Prof Dr-Ing Stephan Reichelt, Universität Stuttgart, ITO; Dr Alexander Bielke, ASML Berlin; Dr Robert Brüning, Carl Zeiss SMT GmbH Jena; Dr Ulrike Böhm, Carl Zeiss AG Oberkochen; Adrian Grewe, Carl Zeiss AG Jena; Marco Hanft, Carl Zeiss AG Jena; Dr Meike Hofmann, Technische Universität Ilmenau; Dr Christof Pruß, Universität Stuttgart, ITO; Dr Henning Rehn, Fisba AG St. Gallen; MSc Christian Schober, Universität Stuttgart, ITO; Dr Christian Sinn, Köln Optik; MSc Nicole Grubert, RWTH Aachen University, TOS; Dr Andreas Walter Stark, Universität Jena; Prof Dr Oliver Baumann, HAW Ham-

burg; MSc Marco Wende, Universität Stuttgart, ITO; Dr Andrea Toulouse, Universität Stuttgart, ITO

DGaO Young Scientists Award

In 2025, the DGaO will again award the DGaO Young Scientists Award for the best dissertation and for the best master's thesis of 2024 in the field of applied optics. Detailed information is available on the DGaO website. Proposals for the DGaO Young Scientists Award can be submitted by January 31, 2025, to the DGaO office (dgao-sekretariat@dgao.de).

Deadlines

Submission of abstracts:	by January 10, 2025 (receipt)
Notification of acceptance:	February 28, 2025
Program mailing and publication:	March 31, 2025
Binding registration:	from the beginning of March 2025
End early-bird registration:	April 30, 2025

Contact

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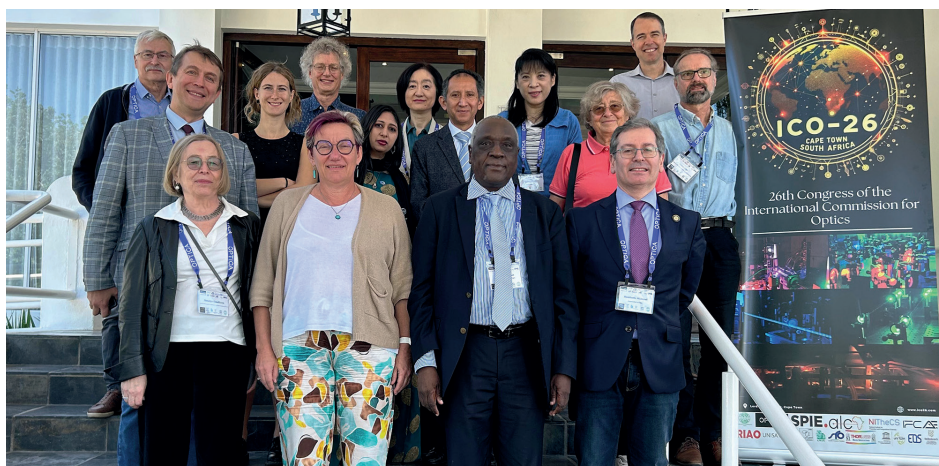
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ICO convenes in Africa for the first time

The 26th Congress of the International Commission for Optics marked a historic milestone, making a premiere appearance on African soil

Gathering delegates from 25 countries across six continents in Cape Town, ICO-26 became a vibrant platform for sharing groundbreaking knowledge and fostering collaboration in the field of optics, with the support of all seven major science societies. Notable keynote speakers included Donna Strickland and Anne L'Hullier, who led the lineup, opening discussions on non-linear optics, high-intensity lasers, and the evolution of attosecond science.

On Thursday October 24th, the election of the ICO Bureau for the term 2024 – 2027 took place during the general meeting. The election was chaired by Prof Roberta Ramponi as past president. The new ICO executive committee is: president Eric Rosas-Solís (Universidad Autónoma del Estado de Mexico, Mexico), past president John Howell (Chapman University, USA), secretary general Humberto Michinel (Uni-



Some members of the previous and new ICO bureau (l-r, back row) Gilles Pauliat, Andrey Naumov, Alessia Candeo, Kent Choquette, Yaseera Ismail, Kaoru Minoshima, Eric Rosas, Yidong Huang, Roberta Ramponi, John Howell, Lothar Lilge, (front row) Nataliya Kundikova, Nathalie Westbrook, Ahmadou Wagué, Humberto Michinel (Source: ICO)

versidade de Vigo, Spain), associate secretary Adrian Podoleanu (University of Kent, UK), treasurer Kent Choquette (University of Illinois Urbana-Champaign, USA).

Concerning the ICO vice presidents, the result was (in alphabetical order):

Alessia Candeo (Politecnico di Milano, Italy), Juergen Czarske (Technische Universität Dresden,

Germany), Andrey Naumov (Moscow Pedagogical State University, Russia), Joseph Niemela (International Center of Theoretical Physics, Italy), Rogerio Nogueira (Watgrid Solutions, Portugal), Yidong Huang (Tsinghua University, China), Kaoru Minoshima (University of Electro-Communications, Japan), and Nathalie Westbrook (University Paris-Saclay, France).

The following vice presidents were appointed by their respective international organizations: Manuel Costa (RIO), Bo Gu (SPIE), Yaseera Ismail (Optica), Lothar Lilge (OWLS), Carmina Londoño (IEEE), Patricia Segonds (EOS), Ahmadou Wagué (LAM).

IUPAP did not appoint their representative to date.

www.e-ico.org

IFR appoints new president

The executive board of the International Federation of Robotics has elected Takayuki Ito as president and Jane Heffner as vice president



Takayuki Ito

Takayuki Ito (Fanuc Corporation) succeeds Marina Bill (ABB), who has held the rotating position since 2022. Ito has more than forty years



Jane Heffner

of experience in the robotics industry. He currently works as chief technical advisor at the robot manufacturer Fanuc Corporation

in Oshino, Japan. Since 1981, he has held various positions at Fanuc: in 1997, he became executive vice president for Fanuc Robotics in North America at the Detroit site; in 2002, he returned to Fanuc headquarters in Japan and took on the role of general manager for the Robot Technology Center.

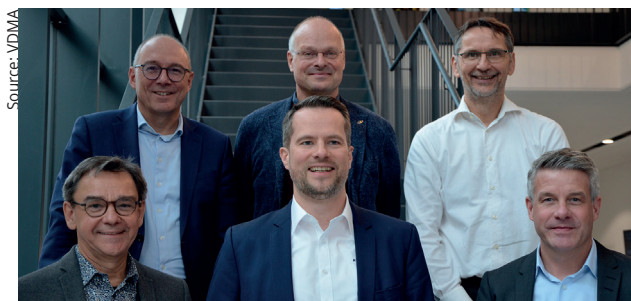
The new vice president of the IFR, Jane Heffner, has more than twenty years of experience in technology-oriented industries,

including robotics, automation, automotive and aerospace. She is currently vice president global sales at Mobile Industrial Robots (MiR), a leading manufacturer of autonomous mobile robots. In this role, Heffner is responsible for the company's global sales strategy from Detroit. Before joining MiR, Heffner held leadership positions at ABB Robotics and other large industrial companies.

www.ifr.org

New board takes up work

VDMA machine vision division elections: Dr Olaf Munkelt succeeds Mark Williamson



VDMA Machine Vision board 2024 – 2027 (top row l-r) Holger Wirth, Dr Olaf Munkelt, Markus Maurer, (bottom row l-r) Dr Horst-Heinol Heikkinen, Daniel Seiler, Hardy Mehl

At the general meeting of the VDMA Robotics + Automation Association, the members of the VDMA machine vision (MV) department elected a new board. Dr Olaf Munkelt, managing director of MVTec Software, was then appointed chairman by the newly elected board.

Dr Munkelt succeeds Mark Williamson, former managing director of Stemmer Imaging in Tongham,

Surrey, UK, whose term of office has ended. Mark Williamson was honored for his contributions and commitment to the European machine vision industry.

“Like many other industries, the European machine vision industry is currently facing many challenges: a weak economy across Europe, geopolitical tensions, uncertainties in many customer industries,

weak demand, and increasing competition. Despite all these challenges, I see many opportunities for the European machine vision industry. It is one of the key technologies for securing the competitiveness of the European manufacturing industry and plays an important role in the trend towards digitalization,” said Olaf Munkelt after his election.

For the period 2024 – 2027, the following company representatives will steer and lead the topics and projects of the VDMA machine vision department: Dr Horst Heinol-Heikkinen, founder and managing director, Asentics (Siegen), Markus Maurer, head of the automation division, Vitronic Machine Vision (Wiesbaden), Hardy Mehl, CFO and COO, Basler (Ahrens-

burg), Dr Olaf Munkelt, co-founder and managing director, MVTec Software (Munich), Daniel Seiler, CEO, AT Sensors (Bad Oldesloe), Holger Wirth, vice president R&D, machine vision solutions division of Atlas Copco, Isra Vision (Darmstadt).

MV on the board of VDMA Robotics + Automation

Dr Dietmar Ley, CEO of Basler, was elected chairman of the board of the professional association at the general meeting of VDMA Robotics + Automation (cf. p. 10).

Furthermore, Dr Olaf Munkelt, Dr Horst Heinol-Heikkinen, and Markus Maurer will represent the MV on the board of VDMA Robotics + Automation.

www.vdma.org

SPIE welcomes 107 new Senior Members

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

SPIE, the international society for optics and photonics, has welcomed 107 new senior members from

22 countries, society members of distinction who are recognized for their professional experience and tech-

nical accomplishments, their active involvement with the optics community and with SPIE, and for significant performance that sets them apart from their peers.

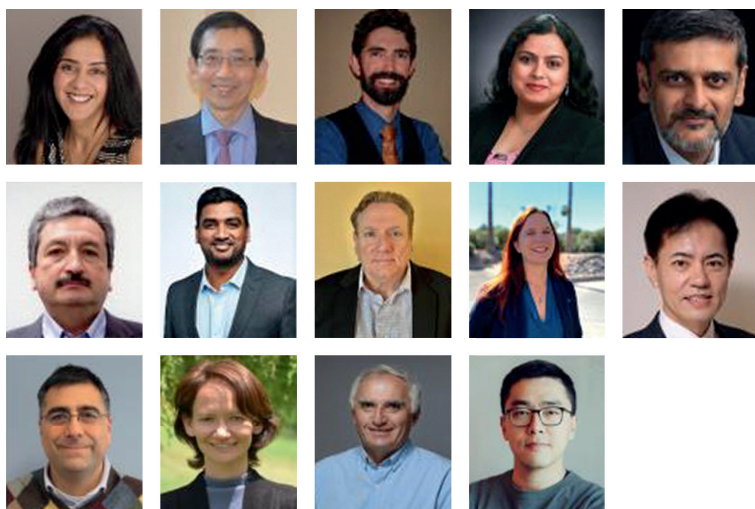
The newly recognized senior members – drawn from across academia, industry, and government – work in a variety of disciplines that include nanophotonics, noninvasive imaging, spectral imaging, laser-matter interaction, optical metrology, quantum optics, metamaterials, medical imaging, optoelectronics, nonlinear photonics, freeform optics, or photonics-industry advocacy, just to name a few.

The industry representatives in the 2024 cohort are Dr Harsha Grunes (Intel),

Dr Chun He (Focuslight), Dr Erik R Hosler (xLight), Srividya Jayaram (Siemens EDA), Dr Anuj J Kapadia (Quadradox), Dr John Khaydarov (MKS Spectra-Physics), Dr Mithun Kuniyil Ajith Singh (Cyberdyne), Kevin J Liddane (POG Precision Optics Gera), Dr Kate Medicus (Ruda Optical), Dr Seiji Nagahara (ASML Japan), Dr Sarper Ozharar (NEC Labs America), Dr Katy Roodenko (Max-IR Labs), Alexander Tritchkov (Siemens EDA), and Yang Zhao (Meta).

Nominations for the 2025 cohort will be accepted through 15 March, 2025; nomination support materials until 1 April, 2025.

<https://spie.org>



(l-r) Harsha Grunes, Chun He, Erik Hosler, Srividya Jayaram, Anuj Kapadia, John Khaydarov, Mithun Kuniyil Ajith Singh, Kevin Liddane, Kate Medicus, Seiji Nagahara, Sarper Ozharar, Katy Roodenko, Alexander Tritchkov, and Yang Zhao (Source: SPIE / Wiley)

EPIC Technology Meeting at ICFO

Cross-disciplinary collaboration with photonics is key to advancing the medical field

Introducing new medical devices into healthcare is a challenge due to strict regulations and the extensive training medical professionals need for new technologies. Despite this, adoption of innovations like photonics is growing, as highlighted during the EPIC Technology Meeting on Photonics Technologies for Medical Diagnosis and Treatments at ICFO in Barcelona, Spain. This event emphasized the necessity of cross-disciplinary collaboration for progress. Curated by EPIC and ICFO, it united researchers, medical professionals, and the entire value chain of photonic technologies for diagnostics and treatment.

Key topics included skin cancer diagnostics, featuring innovations like dermoscopy, confocal microscopy, and OCT. Intraoperative tools such as Raman spectroscopy and hyperspectral imaging were showcased for improving tumor margin assessments. Discussions also covered noninvasive monitoring, such as diffuse optics for cancer therapy and glucose measurement using midinfrared spectroscopy.

Emerging technologies, such as photonic chips for biomarker detection and VCSEL arrays for photoacoustic imaging, promise to revolutionize precision medicine. These innovations



Group photo from the event at ICFO (Source: ICFO)

pave the way for improved diagnostics, personalized therapies, and better surgical outcomes, ensuring photonics plays a vital role in the future of healthcare.

Next year, the EPIC community will meet at the Gustave Roussy institute in France to discuss advancements in cancer care and surgery.

<https://epic-photonics.com>

Save the date for EPIC upcoming events:

- 13 January 2025
EPIC Online Technology Meeting on Photonics for the Quantum Industry
Online Event
- 15 January 2025
EPIC Online Marketing Meeting: Introduction to the World of Email Marketing II
Online Event
- 21 January 2025
EPIC Market Report on Premium Display Technologies by Ian Hendy
Online Event

EPIC Events in San Francisco in January 2025:

- 27 January
EPIC SUMMIT on Optimizing and Scaling Photonics Manufacturing in San Francisco

- EPIC Executive Networking Reception in San Francisco
- 28 January
EU Projects, Pilot Lines & Innovation Hubs Breakfast
EPIC VIPs Networking Lunches and Reception in San Francisco
EPIC Members Networking Reception in San Francisco
- 29 January
EPIC Executive 5 Miles Run in San Francisco
EPIC Members Lunch in San Francisco
- 30 January
EPIC Members Run in San Francisco

- 10 February 2025
EPIC Online Technology Meeting on Fiber Sensors for Industrial Applications
Online Event

- 12 February 2025
EPIC Market Report on Semiconductor Laser Industry by YOLE Group
Online Event
- 21 February 2025
EPIC Sustainability Workgroup Meeting
Online Event
- 24 February 2025
EPIC Online Technology Meeting on Metasurfaces
Online Event

For the list of all events, visit:



<https://epic-photonics.com/epic-events>

If you are asked to take a risk, accept the challenge

Imran Mukhtar, business director emerging technologies in advanced optics at Corning Incorporated, talks to Lidia Briquets, program manager at EPIC.

What is the background to your appointment as business director at Corning?

My parents are Pakistani, but I grew up in Saudi Arabia where my father worked as an electrical engineer. In 1992, I finished high school in Jeddah and moved to the United States to pursue a bachelor of science degree in mechanical engineering and mathematics at the University of Alabama. As part of the program, I worked as an intern engineer for a copper tubing company, where I got my first taste of manufacturing floor processes.

After graduating, I worked in various quality, project management, and operations roles, which eventually led to manufacturing leadership roles. I also completed an MBA in that period. One of the highlights was an expatriate opportunity in Monterrey, Mexico, where I was appointed as plant manager.

In 2006, I made my first foray into glass – working for a company that made glass tubing for pharmaceutical applications. Unfortunately, that company was acquired in 2009, and my



Source all images: Corning Incorporated

position was made redundant. Following that experience, I worked for a couple of years for two family-run companies until 2011 when I joined Corning as a manufacturing strategy manager.

Over the next 13 years, I worked my way up through various roles, leading manufacturing and operations. In 2017, I joined Corning's advanced optics business as the division manufacturing director, and in February 2024 I was appointed business director, emerging technologies.

Glass, which is on more than eight billion devices and growing. And Corning optical fiber drives network connectivity across the globe to bring information to your fingertips at lightning-fast speeds. Did you drive to work today? Corning invented the cellular ceramic substrate at the heart of catalytic converters, which have helped to reduce car emissions by up to 99 % for most tailpipe pollutants compared to the 1960s.

These are a few examples of Corning innovation in your daily life, and our business units continue to be significant players in several key industries through our five market-access platforms: optical communications, displays, automotive, mobile consumer electronics, and life sciences. Innovation is at the heart of Corning's business model, and strong working relationships and deep collaboration are the foundation of how we invent, make, and sell our solutions. We are at our best while operating and working closely with our customers to solve their toughest problems.

To serve the optics and photonics industries, our specialized business called Corning Advanced Optics helps to solve our customers' optical chal-

At a corporate level, what are Corning's main products and markets?

For nearly 170 years, Corning has been solving tough problems and improving people's lives with glass and materials science. From helping a young inventor named Thomas Edison produce the first glass light bulbs in 1879 to inventing the world's first low-loss optical fiber in 1970, Corning innovation is embedded in nearly every part of our daily lives. In fact, just this morning, you have likely touched Corning innovations multiple times just through our diverse businesses.

If you look at your phone, the cover glass may have been Corning Gorilla

Company

Corning Incorporated

The company's diverse advanced optics portfolio reflects our deep understanding of the properties of light, its interaction with matter, and the instruments used to detect it. For decades, Corning has been a trusted optics collaborator with leaders in a wide range of markets, including aerospace and defense, semiconductor materials and optics, telecommunications, and glass ceramics. It offers a diverse set of optics technologies providing solutions to full complex systems. Customer collaboration is the hallmark of their operations.

www.corning.com

Meet us at SPIE Photonics West, Booth 1533

Corning EXTREME ULE Glass will help semiconductor industry leaders mass-produce leading-edge chips vital to advanced artificial intelligence technologies



lenges by applying advanced materials, systems, and design expertise.

What advanced optics products do you manage?

I am responsible for three of the company's strategic investments in through-glass via (TGV) and metallization technologies. I also manage Corning Varioptic Lenses, a global pioneer in adjustable liquid lens solutions, based in France.

In Varioptic, we start with two liquids – a drop of what we call an oil phase and, on top of that, we put a conductive liquid, which could be salted water or electrolyte. Next, we apply voltage to an electrode, which changes the shape of that drop to create an aspherical lens: just imagine a drop of liquid on a glass surface for example. Using a principle called electrowetting, we change the focusing distance of that lens with voltage, resulting in cutting-edge functions such as fast auto focus, image stabilization, continuous tilt, and astigmatism control.

This is an exciting technology because it eliminates moving parts, and different voltages produce different shaped lenses so the technology can be used in a variety of applications such as industrial barcode scanning and machine vision. Our liquid lenses and associated products are also used in applications that require variable focus lenses, such as medical and life sciences, AR/VR, biometrics, and the automotive applications. And the benefits are clear: no moving parts, hundreds of millions of cycles of endurance, low power consumption, and higher speed to name just a few.

What are the factors of Corning's success? We develop close relationships with our customers to understand their technology roadmaps and we look for places where we can support them with our

product base, capabilities, and appropriate capital investments.

I am proud that Corning is one of the few global companies that continues to engage in exploratory research, with more than a billion dollars invested annually in RD&E. A lot of our budget is allocated to what we call 'patient capital', and this includes long-term investments in technology. An example is our optics business, which now supports nearly every step of the semiconductor manufacturing process.

In the 1930s, Corning invented the most immaculate commercial glass product on Earth – an ultrapure glass that would eventually become known as Corning HPFS Fused Silica. This world-changing innovation was used initially in Space Shuttle windows and telescope mirrors. Years later, this material and the process to produce it, chemical vapor deposition, was the starting point for the breakthrough in the optical communications revolution, and later for semiconductor manufacturing.

What are your main challenges?

The photonics and optics industry moves at an extremely rapid pace of innovation and requires deep collaboration with industry leaders in a wide range of markets from aerospace to defense, semiconductor manufacturing, telecommunications, and glass ceramics. We have therefore built a culture that optimizes for speed, responsiveness, and relationship building, combined with deep expertise in our core markets to supply solutions that meet the industry's technological roadmaps.

Corning has a long history of developing strong relationships with our customers across all our market-access platforms, and the relationships that we have built with the world's leading optics manufacturers have allowed us to move in lockstep with them as they

design their next-generation applications. For a material, component, and systems supplier, these relationships and ties to early product development are unlike any other in our industry.

How do you see the future?

I am very optimistic. We will continue to support our customers to achieve what we call the next node of technology – particularly in relation to the semiconductor revolution that is pushing an increasingly smaller form factor. We will continue to do whatever it takes – whether it is the expansion of our current capabilities or developing new capabilities – similar to what we have done with liquid lenses and our recently unveiled Corning EXTREME ULE glass, which allows manufacturers to use the most advanced photomasks to pattern and print the smallest, most complex chip designs.

What is your advice to the next generation of entrepreneurs?

If an opportunity comes to you and you are asked to take a risk, accept the challenge. When younger colleagues come to me for career advice, I always tell them to take the chance. Continue to build out your skill set. If someone is asking you to do something, it is because they believe in your capabilities. This is what I call the unseen hand – the actions in the background that advance your career, even if you don't realize it at the time. Go, take the chance, and make something of it, and have the belief that yes, you can.

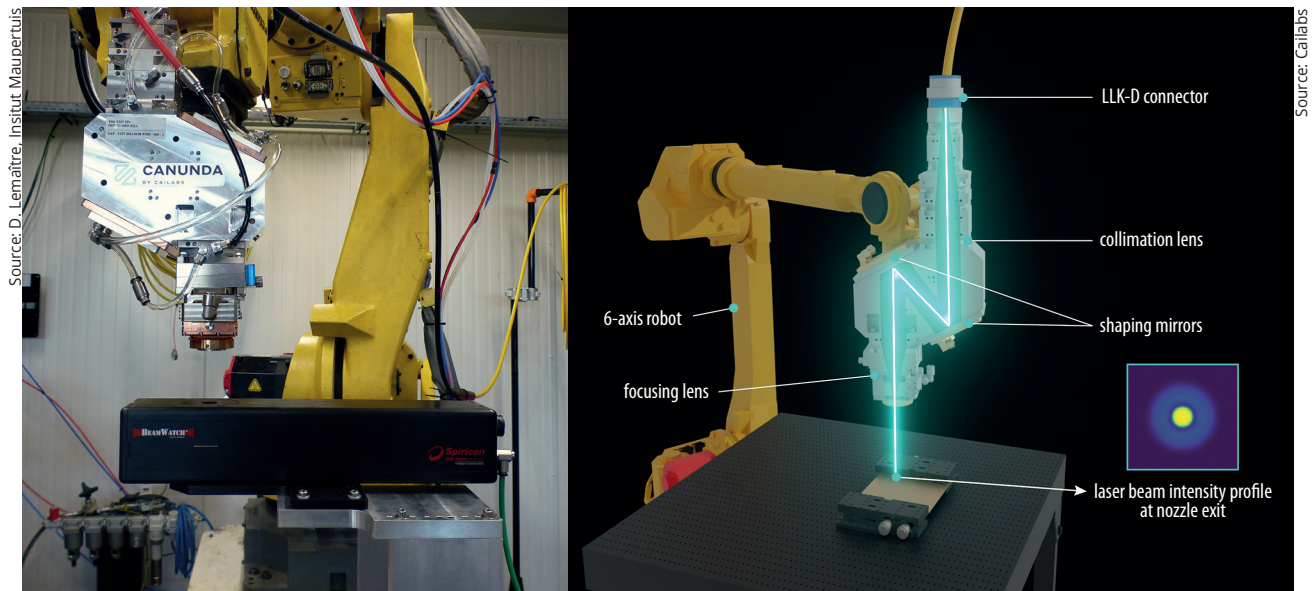
Second, continue to learn. If you are not learning, you are not growing.

*

Lidia Briquets, EPIC – European Photonics Industry Consortium, 17 Rue Hamelin, Paris, France; e-mail: lidia.briquets@epic-photonics.com, Web: www.epic-photonics.com

Shaping high-power laser beams for superior welding

Cailabs relies on an Ophir BeamWatch non-contact beam profiler to develop and analyze high-power laser processes



Laser-based processes require an extraordinarily high level of precision. A key issue with high-power lasers in welding applications is the focal shift. Cailabs has developed innovative beam shaping modules that minimize focal shift and maximize the quality of the weld seam. To analyze the laser beam and demonstrate the technology's superior results, the team relies on renowned institutions and MKS measurement technology.

Cailabs' success story starts with the invention of MPLC (multiplane light conversion), a proprietary technology invented in 2010 by Jean-François Morizur, co-founder and CEO of Cailabs, and Nicolas Treps. Since its official foundation in 2013, Cailabs has designed and manufactured groundbreaking photonics products for core applications in the industrial, telecommunications, and space sectors.

In the industrial arena, the company has been at the forefront of developing new beam shaping technology, unlocking new potential, and improving the efficiency, quality, and safety of high-power laser applications. Close cooperation of the deep-tech company with several institutes globally enables the company to bring their technology into real-world surroundings and help their partners to optimize processes. In 2024, Cailabs was

awarded the Innovation Award Laser Technology 2024 (3rd Prize) at the AKL International Laser Technology Congress in Aachen, Germany.

Welding and measuring challenges

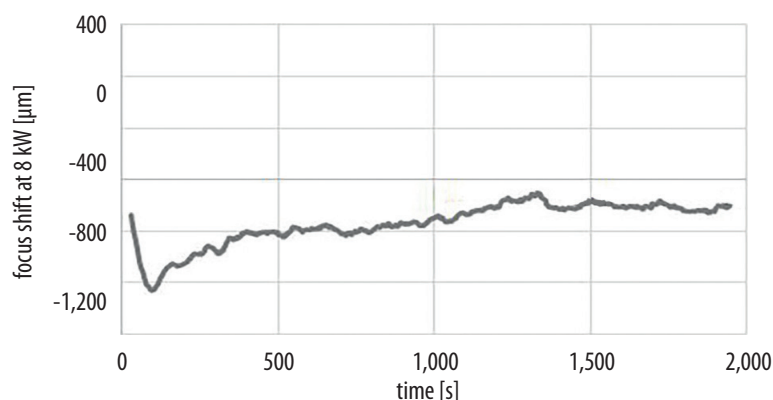
Laser welding offers numerous advantages in automotive production and opens up new technical designs when it comes to electrical vehicles; for instance, laser-welded busbars connecting individual battery cells, or hairpin stators that replace traditional coil-wound designs.

Joining two materials together is generally no easy task. When welding metals, the heat input must be selected in such a way that as little spatter as possible is distributed, no cracks occur, and the melting area neither collapses nor has porous areas. This is when

▲ Configuration for the measurements with the Ophir BeamWatch (l), infographic for copper welding with a Canunda-HP (r)

beam shaping technology can make a significant difference: the shape of the beam significantly influences the quality of the weld seam. However, to enhance the welding process, the parameters of a laser need to be determined carefully beforehand and they need to be stabilized during the entire process. Here comes the challenge when working with very high power: due to the high energy applied, transmitting optics will heat up and there is a chance that thermal lensing occurs, causing a focus shift on the working plane. Once the focus shifts, the parameters of the beam will significantly change, leading to a substantial loss of quality. To pre-

Fig. 1 The BeamWatch system observes a maximum focal shift of only 1 mm at 8 kW over multiple minutes for the Canunda-HP ring shaper laser-head vs centimeters with standard LBW heads



vent this effect, Cailabs' Canunda-HP beam shaping modules not only modify the shape of the beam but also use only reflective optics to make this happen.

Testing and analyzing the beam

Developing innovative technology based on high-power lasers raises the question of how to analyze and verify the results of the new shaping technology. In addition to inhouse measurements with MKS measurement technology such as Ophir power sensors and meters, the experts at Cailabs have established a strong partnership with the Institut Maupertuis. The French center of industrial expertise with a high-quality test platform and equipment utilizes the Ophir BeamWatch non-contact beam profiling system, MKS' high-end measurement technology. Gwenn Pallier, product line manager with Cailabs explains: "We have been fully aware that measuring the focal shift is key to verify the efficiency of our modules. It was a perfect fit that Institut Maupertuis has already been using the only non-contact beam profiling device that allows those real-time measurements. The results delivered with the Ophir BeamWatch profiling system are key to our development process."

Optimizing busbar welding

There are various applications for Cailabs' beam shaping modules, with many of them in the automotive industry. For

example, the Canunda-HP head for copper welding was used at the Institut Maupertuis to perform welding on 10 mm thick Cu ETP copper samples to optimize the bus bar welding processes. The delivered beam consists of an intense core plus a surrounding ring at lower power. The tests were carried out under the optimal conditions (8 kW, 6 m/min), varying the position of the focal point. Measurement of the focal position was taken by the BeamWatch device. David Lemaître, CTO of Institut Maupertuis, outlines: "The Ophir BeamWatch profiling system delivers the key parameters by measuring the Rayleigh scattering of the laser beam. As the beam itself is not even touched, we are able to analyze high-power laser beams with no upper limit while the device itself is lightweight and easy to handle."

Measurement technology inspires confidence

The automotive industry adheres to stringent processes and regulations. Introducing new manufacturing technologies requires rigorous testing to ensure the quality of the produced parts. The Canunda-HP ring shaper generates an annular beam profile with a long depth of field and minimal focus shift. These attributes can only be measured with non-contact, real-time beam profiling technology, making the measurements taken with the Ophir

BeamWatch device at Institut Maupertuis crucial for Cailabs. As Pallier explains, "Being able to verify the stability of our beam shaping modules is very important for our potential customers. I am sure that we were able to win some just because of the measurements taken with the Ophir BeamWatch device."

*

Case study authored by Dagmar Ecker, Claro! Text and PR, on behalf of Ophir. All trademarks are the property of their respective owners.

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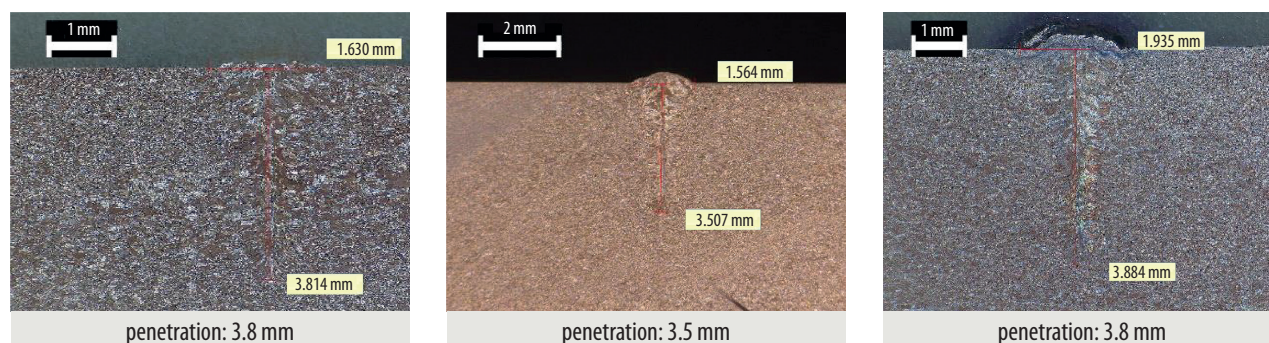


Fig. 2 Penetration depth at different focus position for copper welding with Canunda-HP

Preparing to mass produce photonic devices

Advances in active alignment engines for efficient photonics device test and assembly

Scott Jordan & Stefan Vorndran



Source: PI

Over more than a half century, the pace of innovation in electronic communication and computing has consistently increased, giving rise to progressively smaller silicon microchips with enhanced processing power. This achievement is attributed to the exponential growth in the density of integrated circuit (IC) transistors, a development predicted by Intel co-founder Gordon Moore in 1965 and commonly called Moore's Law. However, there are inherent limits to reducing the physical feature size of silicon structures before quantum effects start influencing their functionality.

Fortunately, photonics has come to the aid of electronics, enabling the integration of miniaturized optical devices into various applications, from sensors in wearable devices, to lidar and ADAS cameras in autonomous vehicles. Photonics has the potential to surpass traditional electronics combining data throughput and efficiency with miniaturization, sparking a true revolution in the telecommunications and data communication sector. To sustain this growth, it is essential to address the remaining challenges and bottlenecks

in photonic device manufacturing. The implementation of additional automation solutions, especially those ensuring fast and precise component alignment, is crucial to meet the demands of future advancements.

Limitations of labor-intensive device assembly

The assembly process of photonic devices typically includes meticulously aligning, gluing, and curing a combination of light sources, fibers, lenses, gratings, and chips with array I/Os

and active and passive elements. Each of these individual components must be accurately positioned to ensure the intended functionality and performance of the final product, as even slight misalignments on the orders of less than a millionth of a meter can severely impact device efficiency.

Despite technological advancements, many manufacturers still rely on manual alignment techniques. Beyond being time-consuming, these methods often involve specialized labor that is both costly and challenging to find.

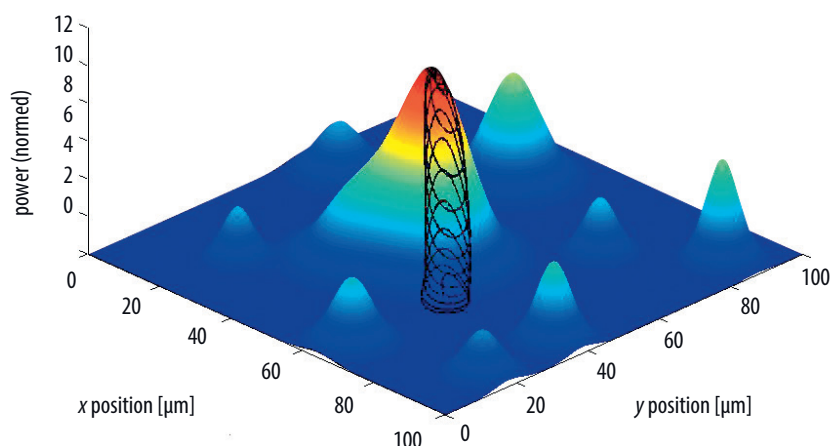


Fig. 1 Optical power distribution of a photonic component and simulated hill-climb algorithm (gradient search; source PI)

The manual assembly of complex devices can take up to twenty minutes, creating a significant bottleneck in the production process at the component positioning stage. Traditional approaches to precision assembly (jigs, tooling, fixturing ...) fail to address the stringent optical tolerances required. An alternative alignment strategy is necessary to precisely indicate component positioning.

Optical feedback to guide automatic alignment engines

A key characteristic of photonic devices is their efficiency's direct correlation with the alignment of individual components. This means that the output strength dynamically changes in real time with component positions. Until now, the varying signal strength served as a guide for iterative positional adjustment processes, resulting in a precisely aligned assembly. Today, as discussed below, novel technology allows these processes to be performed in parallel, for typically 99% process-time reduction. To assess component drift, the

fluctuation in photonic output strength can be monitored during the gluing and curing process. However, manually performing this method on complex devices with numerous inputs and outputs becomes impractical. Optimizing one connection can lead to movement – physical or optical – affecting others, necessitating constant readjustment for a global consensus. An automated solution is essential to address this challenge, enabling a practical production process that eliminates the need for time-consuming back-and-forth adjustments.

Automating the adjustment process involves closing the feedback loop between device output and positioning hardware, allowing intelligent software solutions and control modules to handle fine-tuning. These systems utilize areal scan algorithms to characterize the assembly, identifying the approximate location of peak photonic output. Multiple gradient searches are then conducted to precisely determine the global optimum. Specialized piezo nanopositioning devices, capable of

adjusting several connections simultaneously, guide the components into perfect alignment in an innovative process known as active alignment. Integrated features, including compensation factors, eliminate the need for constant iterative readjustment. Complete modular solutions are now available, significantly reducing photonic device manufacturing times while maintaining sub-micron precision. Physik Instrumente's Fast Multichannel Photonic Alignment (FMPPA) technology, for instance, can perform multiple alignments, such as in and outputs, across multiple-degrees of freedom, in parallel, reducing assembly time by a factor of one hundred or more.

Company

Physik Instrumente (PI)

PI with headquarters in Karlsruhe, Germany, is the market and technology leader for high-precision positioning technology and piezo applications in the market segments of industrial automation, photonics, semiconductor, and microscopy and life sciences. Working closely with customers around the world, PI's more than 1,700 specialists have been continuously pushing the boundaries of what is technically feasible for more than fifty years. Various drive technologies, internally developed sensor technology, electronics, and control technology provide the basis for this. PI's portfolio ranges from components to subsystems to tailor-made complete solutions. More than 560 granted and pending patents underline the company's claim to leadership in the fields of precision positioning and piezo technology. PI operates on a global scale, with nine production sites in Europe, North America, and Asia, as well as sixteen sales and service subsidiaries.

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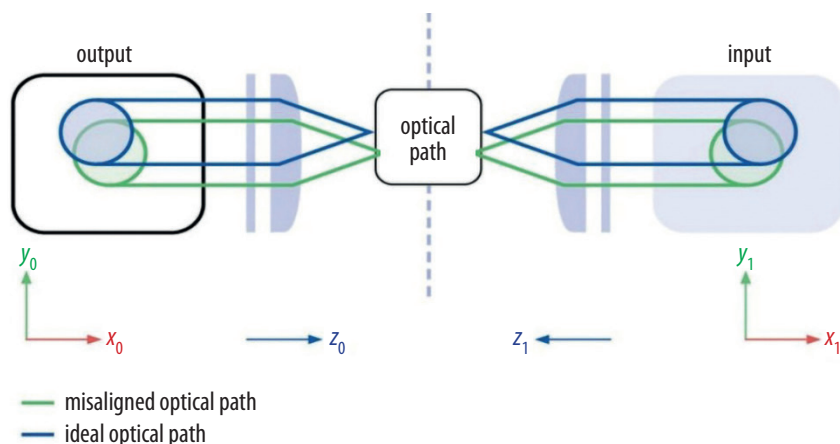


Fig. 2 Testing and packaging of modern photonic devices can be a huge challenge across multiple degrees of freedom. The alignment of multichannel devices, such as fiber-optical arrays, used to be a slow, repetitive process before modern parallel algorithms were developed. (Source PI)

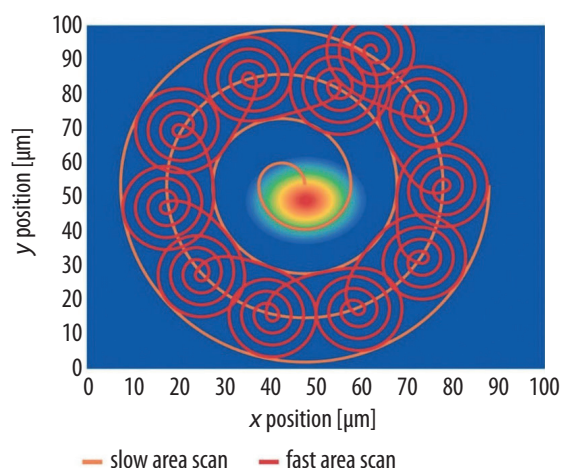


Fig. 3 Optical feedback is the key to automated alignment. A fast, traditional way of finding first light followed by a gradient search for optimum coupling efficiency is shown above – a double spiral scan using a hexapod/piezo approach. The hexapod runs a coarse spiral scan (coarse meaning single digit microns), while the piezo stage fills in the gaps with high-speed sub-micron scans. Both fine and coarse scans can be executed simultaneously. (Source: PI)

Solving the first light capture problem

Since alignment is the top cost driver for photonics device manufacturing, addressing it has been PI's focus since the award-winning Fast Multichannel Photonics Alignment (FMPA) technology in 2016. By performing optimization in parallel across multiple channels, components and degrees of freedom and achieving coupling repeatability to typically 0.02 dB, FMPA reduces the time and cost of manufacturing and testing of photonic devices and improves yield. But before the optimization process can even start, an optical signal, above the noise level, needs to be detectable – this process is called first light capture, and it is particularly time-consuming in devices with inputs and outputs where both sides must be lined up for even a threshold amount of coupling to be achieved. Finding first light has been a time-consuming procedure in all industrial photonics alignment applications, including wafer probing and device packaging.

Now, a breakthrough has arrived in the form of a novel, built-in search-and-alignment algorithm (patent applied for), promising to revolutionize this field. The algorithm, dubbed PILightning runs embedded on PI's advanced controller. It enables highly dynamic mechanics such as piezo scanners or direct-drive air bearing stages to achieve significant production-economics gains over previous first light search algorithms. This new process is fully automated and virtually instantaneous, eliminating the need for extensive calibration or manual intervention. PILightning is based on a new search method with integrated AI-based real-time executive function. It also replaces fine pitch scanning by high frequency data sampling, raising alignment speeds significantly. It drastically reduces the time required to acquire first light in single and double-sided couplings and in loopback (omega) waveguide configurations.

Once first light is detected, the FMPA fast gradient search algorithm takes over, utilizing real-time feedback

control to swiftly optimize the alignment in parallel across the degrees-of-freedom and channels. Depending on the application, a tracking algorithm can also be activated to maintain maximum coupling efficiency – important, for example, in curing situations.

Modular solutions based on multiple drive technologies

The photonics market is advancing rapidly, with projected substantial growth in a large number of sectors incorporating this technology in the next decade. Anticipating devices with hundreds or even thousands of individual components and connections, manufacturers face the necessity of parallel optimization, making active alignment the optimal choice to meet production demands.

Additionally, as photonic devices gain traction across various sectors, the development of increasingly specialized devices requires bespoke production processes. Manufacturers aiming to stay competitive and adapt to evolving demands require flexible combinations

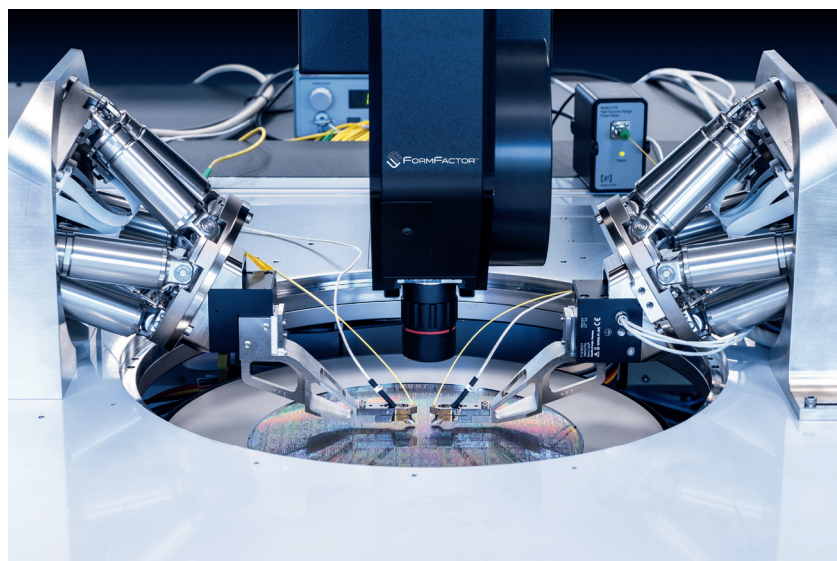


Fig. 4 The F-712, double-sided 18-axis fast multichannel photonics alignment engine provides fast NxM alignment of SiP devices in wafer probers. The hexapods provide six degrees of freedom, while a compact 3-axis piezo scanner achieves nanometer resolution and scanning frequencies to 100 Hz for fastest possible alignment. Cascade Microtech's pioneering CM300xi photonics-enabled engineering wafer probe station integrates PI's Fast Multichannel Photonics Alignment engines for high throughput, wafer-safe, nano-precision optical probing of on-wafer silicon photonics devices. (Source: FormFactor)



Fig. 5 A Pilightning-algorithm enabled dual sided air-bearing-based alignment system. The new algorithm reduces the first light finding process in single-sided applications by 10× or more and in dual-sided applications by several 100×. (Source: PI)

of hardware and software that can be easily reconfigured.

In addition to ‘monolithic’ hexapod-based 6-axis alignment engines, modular alignment solutions, exemplified by those developed by PI, excel in providing the flexibility and scalability necessary for production operations.

These solutions include friction-free air-bearing-based motion systems that require zero maintenance and provide superior speed and lifetime, as well as linear and torque motor driven solutions with precision mechanical bearings, and economical systems based on traditional screw drives and stepper motors.

Common to all these modular systems is a high-performance EtherCat-based motion controller with embedded, advanced alignment routines and integrated, high-speed optical power meter, for a quick path to success.

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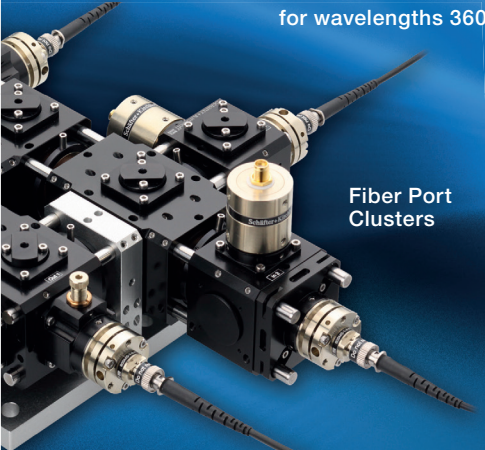
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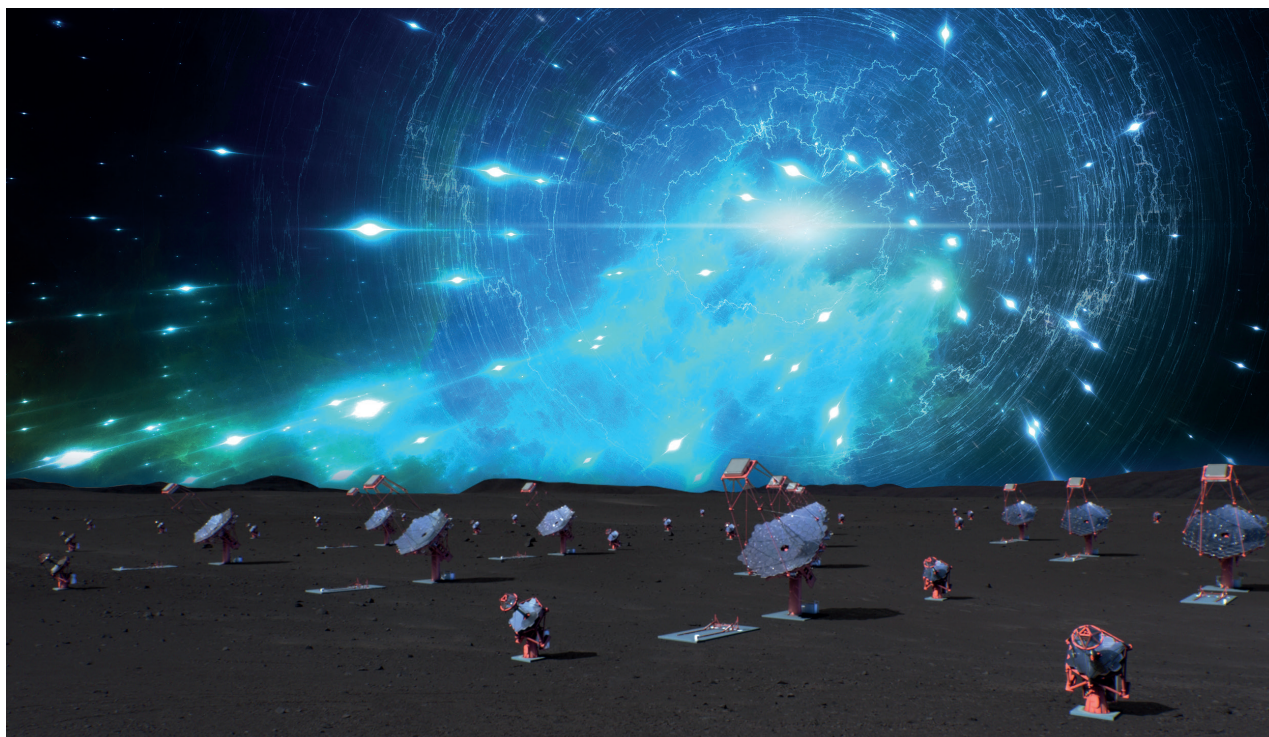
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Behind the science

Many international research facilities rely on photonic technologies



Source: CTAO and Hamamatsu Photonics collage

Hamamatsu Photonics has contributed to the success of numerous scientific research projects by providing advanced optical detectors and sensors. In this article, we reveal these key technologies behind two of the most exciting high-energy physics experiments, the Cherenkov Telescope Array Observatory CTAO and the High Luminosity Large Hadron Collider (HL-LHC) at CERN, which strive to uncover the deepest mysteries of our universe.

CTAO: the glowing blue makeup of our universe

Almost twenty years ago, visionary scientists devised a plan to push the technological boundaries of existing ground-based gamma-ray telescope detectors – HESS, MAGIC, and VERITAS. These telescopes detect the particle showers released by gamma rays reaching our atmosphere. These ultrahigh energy particles create a blue flash of Cherenkov light, helping us to address some of the most perplexing questions in astrophysics. The researchers' desire was to create unprecedented technology in terms of sensitivity and accuracy. Thus, was born the idea of the next generation of telescopes, the Cherenkov Telescope Array Observatory, CTAO, surpassing its predecessors in terms of number, size, and technology.

Fast forward to today, the CTAO is now a multinational project that will become the world's largest and most sensitive observatory for gamma-ray astronomy, supported financially by a growing list of shareholders from more than ten countries and an intergovernmental organization. With more than sixty telescopes located in the northern and southern hemispheres, the CTAO will be up to ten times more sensitive than any current instrument and will explore the very high-energy Universe within an unprecedented energy range (20 GeV – 300 TeV). The CTAO's unique capabilities will help address some of the most perplexing questions in astrophysics. The Observatory will seek to understand the impact of high-energy particles in the evolution of cosmic systems, to gain insight into the

▲ This rendering of CTAO South shows the three classes of telescopes that are required to cover the full CTAO energy range (20 GeV to 300 TeV)

most extreme sources in the Universe, such as black holes, or to search for dark matter and deviations from Einstein's theory of relativity. Moreover, the CTAO will be the first observatory of its kind to operate as an open, proposal-driven observatory providing public access to its high-level science data and software products.

The CTAO was promoted to a 'Landmark' on the European Forum on Research Infrastructure (ESFRI) Roadmap 2018, and was ranked as the main priority among the new ground-based infrastructures in the Astronet Roadmap 2022 – 2035.

Succeeding in creating such a considerable feat demands innovative technology among many things. Many actors proposed ideas and prototypes over the years aiming to find solutions to overcome the various challenges posed by such an ambitious project. Hamamatsu Photonics, present from the very early scientific discussions, competed with its leading technology – the photomultiplier tube (PMT). This was only the start of a journey with many obstacles to face, starting with the customization of a product to exact specifications and trialing it until its success. Not to mention designing different and improved technologies such as Hamamatsu's silicon photomultiplier (SiPM).

The key is blue

The particularity of the CTAO is its sensitivity to the highest-energy gamma rays. Gamma-ray bursts are powerful events generated from some of the most violent environments in our Universe, such as supernova explosions. In fact, the gamma rays produced by these events are a trillion times more energetic than visible light. Identifying them is not an easy task, as they do not reach the Earth's surface. However, when passing through the atmosphere, they produce subatomic particle cascades. As these particles descend into our atmosphere, they lose energy and emit Cherenkov radiation. The ultraviolet and finally visible (mostly blue) fraction caused by secondary particles can then be detected from the ground by the telescopes' high-speed camera.

CTAO's telescopes differ in size and in number as they aim to capture all the various energy spans. First, their large mirrors collect the glowing blue light, which is then detected by the high-speed PMT camera system. The light flashes are so faint and short (a few nanoseconds), it is not possible to see without this highly sophisticated technology. The PMTs detect the light flashes and amplify them in a compact, low noise, and wide dynamic range gain block. The information is then converted into a measurable electronic signal.

Early discussions projected the need for 200,000 PMTs to fulfill the whole range of telescopes. This demanded a colossal undertaking in terms of providing consistent quality to meet custom specifications. PMTs are mostly made

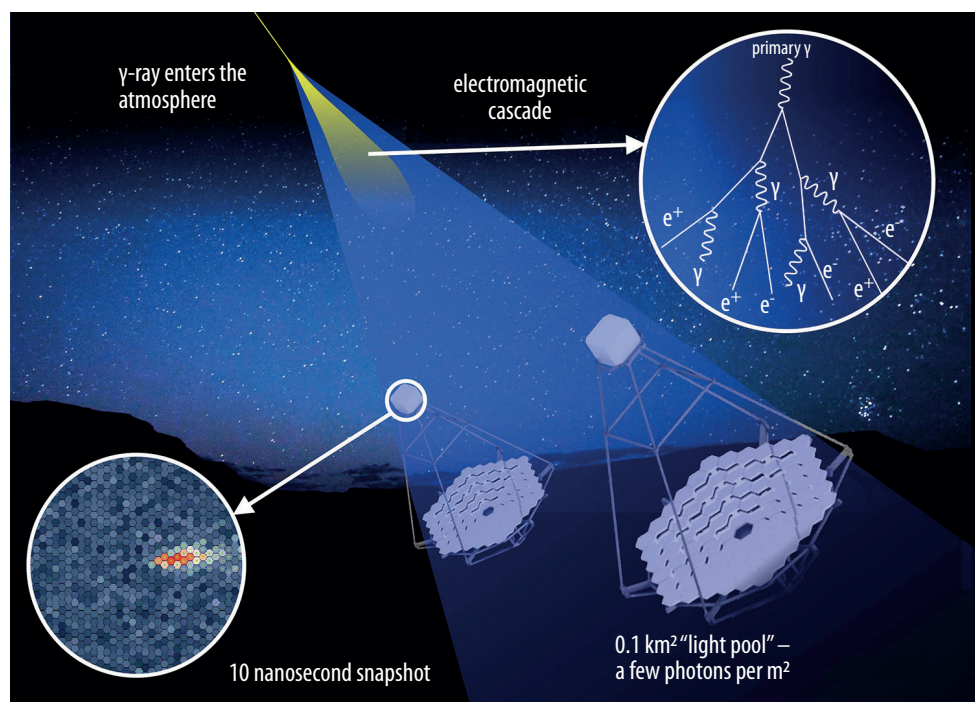


Fig. 1 A gamma ray's particle shower in the atmosphere ultimately produces Cherenkov light that can be detected by special telescopes

by hand, and their assembly is an arduous task. Therefore, manufacturing and testing such a large number throughout each phase is both time-consuming and costly. One of the major pain points was also achieving high sensitivity through high quantum efficiency in order to detect the faintest light signals. This challenge limited the maximum gain of the PMT. Timing, as mentioned, is also crucial; any signal delay means missing or providing distorted data. To maintain the time window low, PMTs need to be fast and small with a highly efficient photocathode.

In addition, the after-pulse generated created a source of wrong signals that had to be minimized. Identifying the root of these challenges lead to a better understanding of materials and procedures in the manufacturing process.

Enabled by the EU FP7 program for the CTAO preparatory phase, many institutes, universities, and their labo-

ratories, in collaboration with Hamamatsu, have been involved in improving these PMT properties. In parallel, given some of the technological challenges surrounding PMTs, the development of highly sensitive light detectors based on semiconductor technology, the SiPM was requested. The shape, dimensions, and microcell size of the SiPMs, were evaluated from a fully customized hexagonal structure to a more typical square with $75 \times 75 \mu\text{m}$ cells. The technology required did not exist, yet scientists collaborating with Hamamatsu researchers worked together to find the optimal solution.

Improving technology over decades of collaboration

Over nearly twenty years of collaboration, scientists and Hamamatsu continue to push design ideas for both PMTs and SiPMs. The evaluation of the PMT design was reviewed and

Company

Hamamatsu Photonics

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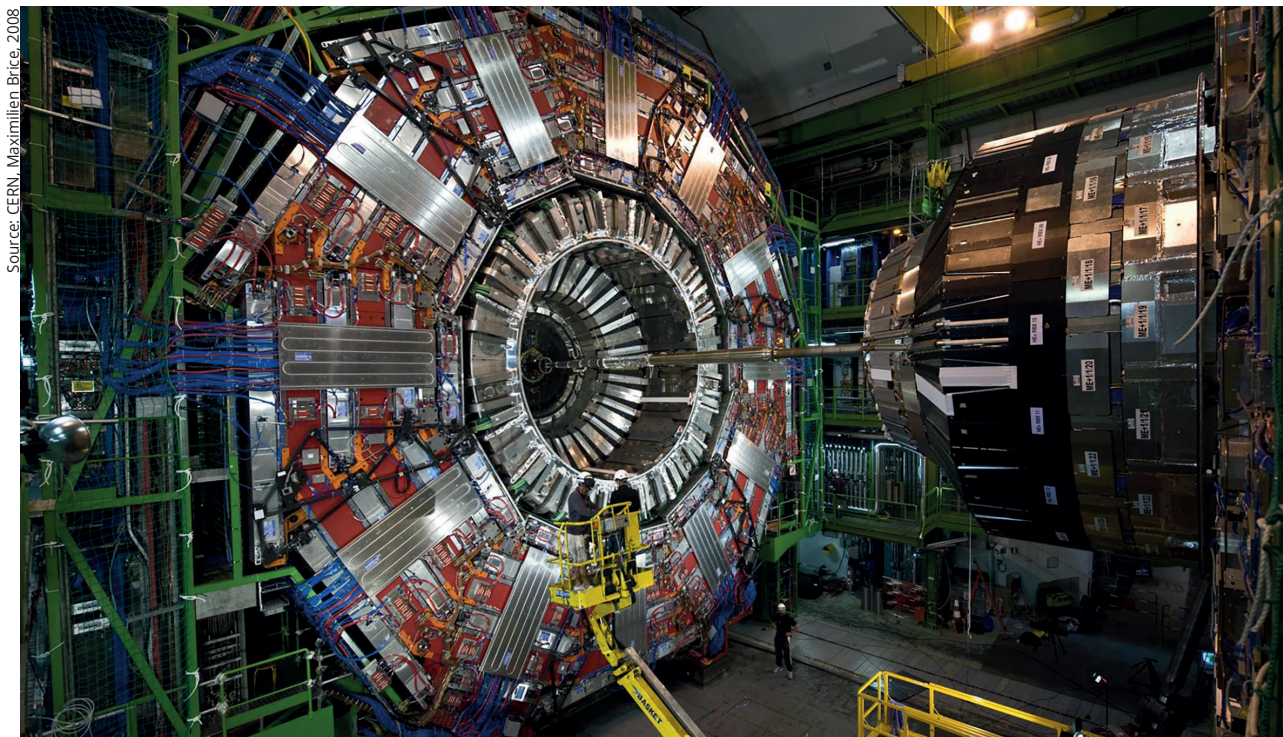


Fig. 2 CMS, one of the Large Hadron Collider's main detectors

adjusted many times creating, for example, the SBA (super-bialkali) photocathode with increased quantum efficiency compared to common bialkali photocathodes. The idea was to replace the 1" PMT with a newly developed one, which limited amplification while still maintaining the advantage of time speed. As there was less gain needed, one dynode was removed.

As the SiPM manufacturing process is quicker – using fewer parts, which can be mass-produced and lightweight materials – they have proven to be more cost-effective in large-scale production. Over the years, their technology improved drastically on many levels. One example is how Hamamatsu limited the crosstalk by adding trenches,

effectively reducing the possibility of fake signals. Another is how the pulses improved over time.

Currently, as CTAO telescopes are in their advanced stages of development, thousands of PMTs and SiPMs are being produced and tested. The expected results obtained from the CTAO will provide insights into distant galaxies and extreme particle accelerators in space. Once completed, the hope is to accomplish a completely new view of the night sky and ultimately our universe.

CERN: the circular power revolutionizing physics

A ring 27 kilometers long of superconducting magnets with a number of accelerating structures currently resides 100 meters underground in the Franco-Swiss border near Geneva. Known for being the world's largest and most powerful particle accelerator, the Large Hadron Collider (LHC) remains the latest addition to CERN's accelerator complex.

Since 2010, when the accelerator became operational, inside it you will find two high-energy particle beams that travel in opposite directions at very close to the speed of light before they are made to collide, thus generating showers of particles which are investigated by the dedicated experiments around the accelerator ring. These powerful experiments have been the driving force behind several major discoveries in physics including the discovery of the 'god particle': the Higgs boson in 2012.

This major breakthrough has brought the scientific world one step closer to understanding our world and the origin of the universe.

Hamamatsu Photonics has been working with CERN on this project, and its planned upgrade, which aims to amplify the performance of the LHC for more potential discoveries after 2029. The upgrade named High Luminosity Large Hadron Collider (HL-LHC) has the objective to increase the integrated luminosity by a factor between five and seven beyond the LHC's design value. Hence, the technology used in those experiments has to meet even more severe conditions, as well as push the limits of what currently exists.

Increasing the demands

The upgrades of the HL-LHC and its related experiments are currently underway to achieve an even higher frequency of proton-to-proton collisions, in order to measure the Higgs boson properties more precisely and to search for dark matter of which little is known.

Although more data can be obtained by increasing the frequency of these collisions, this will generate higher radiation and impact the photodiode (PD) array. The PD array is used in the calorimeter of the CMS experiment, which measures the energy of the particles.

The challenge to solve is the fact that the PD arrays gradually lose their sensitivity while being exposed to radiation. One simple solution is to apply a higher

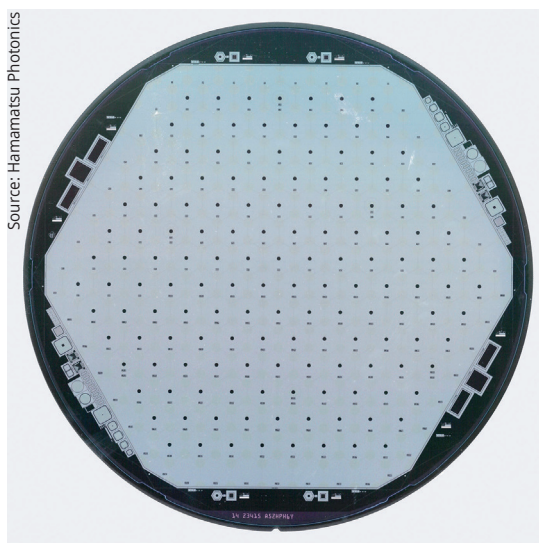


Fig. 3 8-inch pixel array detector

voltage to the PD array to maintain high sensitivity even when exposed to radiation, however, this is only possible to a certain degree.

Additionally, CERN required an even larger-area PD array to reduce both the costs and the dead space of the entire detector system.

The final main challenge was the manufacturing of an even larger-area PD array – never done before – with quantities of circa 27,000 pieces in a short timeframe. Therefore, Hamamatsu was faced with overcoming this while finding the right solution for higher sensitivity in its PD array.

The world's largest photodiode

To meet the high-tech needs of the HL-LHC experiments, Hamamatsu Photonics designed and developed the world's largest photodiode with the highest radiation resistance among PD detectors used in high-energy physics applications. Ideal for particle and radiation detection through the measurement of ionization energy deposits, it has both high resistance to radiation and a large area required for the HL-LHC project.

At first, Hamamatsu focused on the high resistance to radiation aspect. They successfully developed a large-area PD array prototype that can be made from a single 6-inch diameter wafer, is highly resistant to radiation, and operates at voltages as high as 800 V.

To utilize larger-diameter wafers as the material for a larger-area PD array, Hamamatsu installed new manufacturing equipment for an 8-inch diameter. The manufacturing process conditions were reviewed from scratch in order to improve the uniformity of the thin film thickness and impurity concentration formed on the wafers.

By taking these steps, Hamamatsu managed to fabricate a PD array about twice the area of the previous one while maintaining the same high level of radiation resistance and performance characteristics.

Many other technological solutions have been and are currently being designed to support the demanding expansion of the world's most powerful particle accelerator. Each year as we get closer to its operational date, we also get a bit closer to finding out the true nature of our universe.

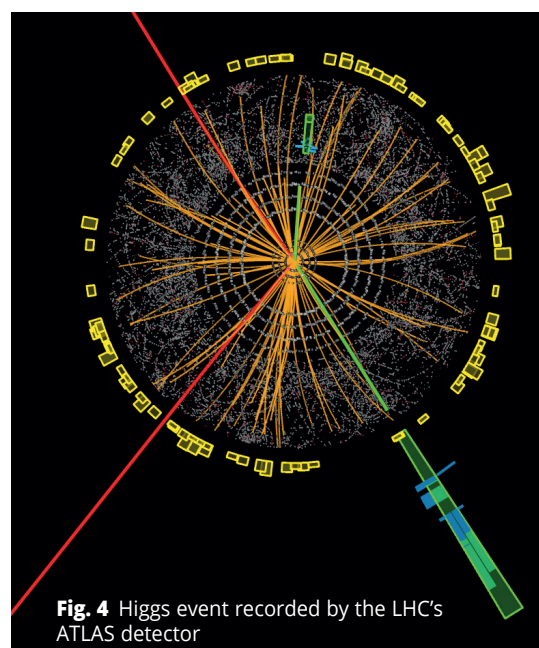


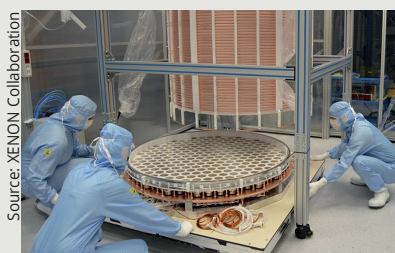
Fig. 4 Higgs event recorded by the LHC's ATLAS detector

Source: CERN / ATLAS collaboration, 2012

Hamamatsu Photonics

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More scientific endeavors



Source: XENON Collaboration

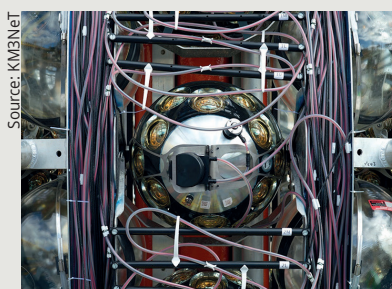
PMT bottom put in place

XENONnT

To unmask the exact nature of dark matter, scientists developed a prototype detector XENON10, which consisted of a dual-phase time projection chamber (TPC) filled with liquid xenon. The aim is to detect dark matter candidates in the form of weakly interacting massive particles (WIMPs) by looking for rare interactions via nuclear recoils in the liquid xenon target chamber. Today, XENONnT, the name of the latest experiment, uses about 8.6 tons of xenon. Hamamatsu Photonics supported the collaboration from the start by providing the first photomultiplier tubes (PMTs) as detectors.

KM3NeT

Deep down in the darkness of the Mediterranean Sea stand hundreds of mysterious vertical strings, each carrying large spherical glass frames stretching far into the distance. This improbable infrastructure is built at 3,500 m below the waves to understand the beginning of our universe through the observation of neutrinos with more than 2,000 Digital Optical Modules. Hamamatsu Photonics was approached to participate in this venture and provide PMTs as ultrafast photosensors.



Source: KM3NeT

Digital Optical Module



Source: NASA, GSFC

FGST in orbit

Fermi

Launched into space in 2008, the Fermi Gamma-ray Space Telescope (FGST) orbits around the Earth every 90 minutes. Its two main sensors on board, the Gamma-ray Burst Monitor (GBM) and the Large Area Telescope (LAT) scan the sky for intriguing events, picking up x-rays and gamma rays within a wide energy range. The observatory team approached Hamamatsu Photonics in 2001 in need for silicon strip sensors. To meet the demanding requirements, the company built a new production line for manufacturing, testing, and delivering 12,500 newly designed 6" Si strip sensors, over the following three years.

Please visit Hamamatsu Photonics' Behind the Science page for more information: <https://hep.hamamatsu.com>

Creating a virtual reality by ion beam technology

Ion beam technology enables the manufacturing of waveguides for AR devices as the next computing platform

Mandy Gebhardt



Source: Adobe Stock / dragonstock. All other images source: Scia Systems

Among the most significant technological challenges associated with augmented reality (AR) and mixed reality (MR) glasses is the production of optical waveguide combiners. For both technologies, surface relief gratings (SRG) are used as the in-couplers and out-couplers of the light into the near-eye displays. This article shows the manufacture of slanted SRGs using ion beam processing as a crucial component of the waveguide.

Augmented reality (AR), mixed reality (MR), and extended reality (XR) have been on everyone's lips for some time. The first devices that came onto the market with AR or MR functions were mainly used in the industrial segment.

The initial applications were in online training, e-learning, and VR-supported maintenance. However, sales are still low due to the devices' bulky shape, heavy weight, and limited field of view (FOV).

The next generation of devices is on the way though that will allow interaction between people and the digital universe – eyeglass-like with an integrated minicomputer. The strategic goal: AR and MR devices as the next computing platform. The expectations of the devices are high: analysts compare the upcoming changes with those of the introduction of the first iPhone in 2007.

It is clear that technology companies and specialty glass manufacturers are not the only ones dealing with the issue. Integrating virtual reality and metaverse technologies sets a clear signal for the future. It is possible to interact with the environment via augmented reality (AR), such as by quickly and easily

Company

Scia Systems

Founded in 2013, Scia Systems is a technology leader in thin-film process equipment based on advanced ion beam and plasma technologies. The systems are used for coating, etching, and cleaning processes with nanometer resolution and have been successfully implemented in various high-tech industries worldwide, including microelectronics, MEMS, and precision optics industries.

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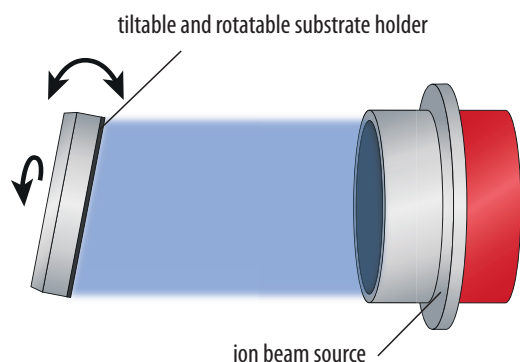


Fig. 1 Scheme of an IBE/IBM process that uses a collimated beam of inert gas ions for structuring or material removal

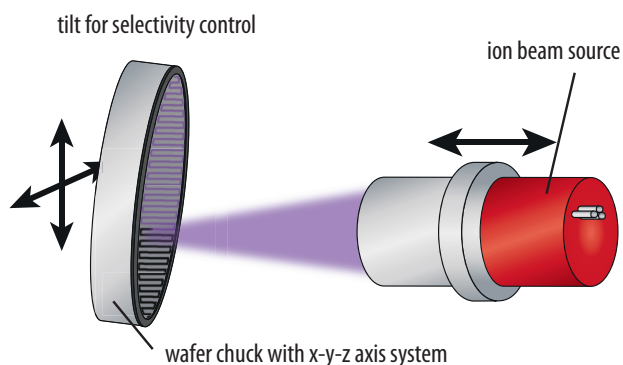


Fig. 2 Scheme of an IBT process; a focused broad ion beam raster scans across the wafer. The local material removal is controlled by adjusting the dwell time

accessing certain information, understanding another language, or being guided from A to B by a virtual navigation system.

However, there are still a few hurdles to overcome before the successful market launch of AR devices. These arise from the technical challenges of AR/MR, the current state of manufacturing technology, and the increasing importance of the economic aspects. Since AR and MR devices will be produced in billions of units, the supply chain will be driven by cost efficiency. The threshold for market acceptance can only be overcome if the end product's price is affordable and attractive to the consumers. To achieve this, stable and cost-effective manufacturing processes with a high level of automation are required to guarantee a long service life and high reliability of the components.

Ion beam etching overview

Ion beam etching (IBE) – also known as ion beam milling (IBM) – is ideal for precise surface processing. The technology uses a directed beam of high-energy ions to selectively remove material from the surface and to create specific patterns or structures. The

ion beam process can combine physical and chemical etching. Physical etching uses the kinetic energy of fast inert ions bombarding the surface to sputter, releasing atoms from the target surface. The process works on all materials facing the ion beam. Chemical etching utilizes a chemical reaction between the reactive ions and the target surface. The reaction products must therefore be volatile.

A broad beam of positively charged ions, typically argon ions, is accelerated onto a substrate. The ions transfer their kinetic energy to the surface atoms, causing them to be ejected, thus removing the material. The ion beam is typically larger in diameter than the substrate size, ensuring sufficient removal uniformity and throughput. The substrate rotates during ion beam milling for the best uniformity. Chemically reactive gases can be added to enhance the etch rate.

The level of material removal can be adjusted precisely to achieve a perfect etching structure with superior homogeneity by varying the angle of incidence and the substrate rotation speed. This enables many different geometries to be created in a broad spectrum of

processable materials. This is why ion beam etching is an ideal method of processing transparent materials used for AR devices.

Ion beam trimming

Ion beam trimming (IBT) is a particular type of IBE that uses a focused broad ion beam of positively charged ions (e.g., Ar^+) to etch material from a substrate by ion bombardment. A beam width of typically 8 – 15 mm (FWHM) ensures a sufficient lateral resolution and a high throughput. The ion beam meanders across the substrate surface during trimming. The material thickness and the device properties such as the frequency of acoustic filters can be precisely adjusted by altering the local dwell time. A reactive structuring of the surface – the so-called reactive ion beam trimming (RIBT) – is achieved by introducing an additional reactive gas into the ion beam source.

Advantages of ion beam processes

Ion beam processes offer several advantages: they can be used on almost all materials; ion beam machining is always contactless and nondestructive

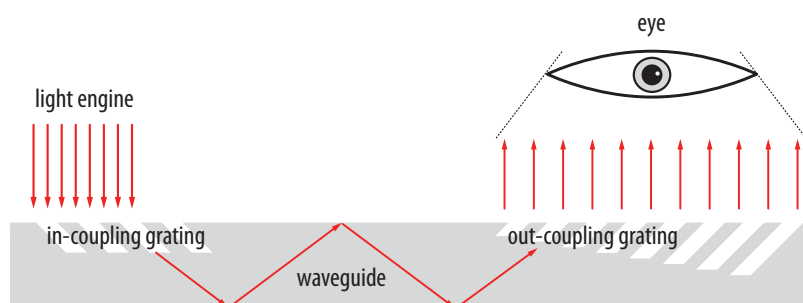


Fig. 3 Scheme of an optical grating that is used for coupling the light from the source into the waveguide glass and out of it towards the eye

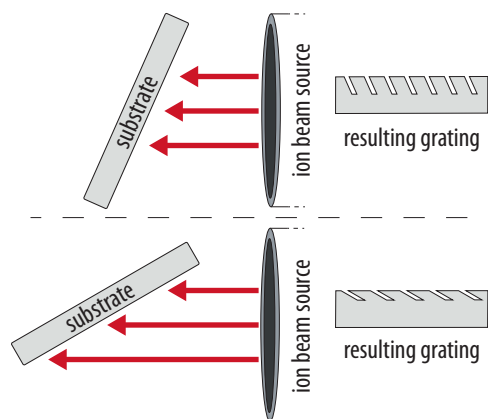


Fig. 4 Ion beam etching of gratings under different angles of incidence

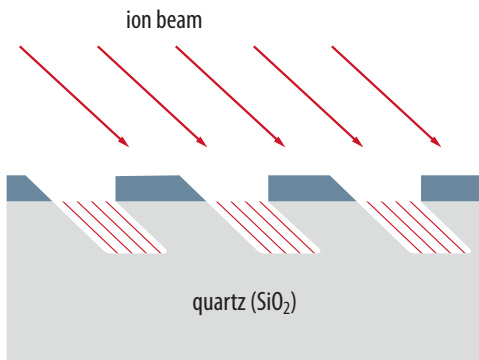


Fig. 5 Scheme of an etched quartz grating

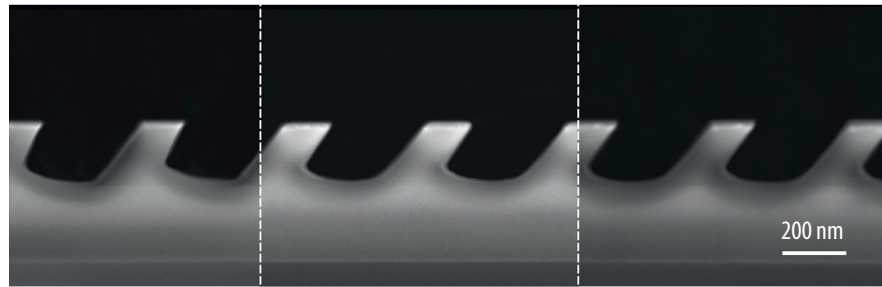


Fig. 6 REM pictures of slanted relief gratings with a high aspect ratio, etched with an angle of incidence of 40°

and does not create mechanical stress on the substrate's surface, avoiding any subsurface damage; the ion beam current, energy, and etching rate can be independently controlled, allowing for precise material removal and excellent uniformity across the etched surface. Furthermore, ion beam processes offer high resolution, making them suitable for detailed, intricate designs and side-wall shaping. These advantages make ion beam processes powerful tools for precise surface processing.

The display – the core of each AR device

Among the most significant technological challenges associated with AR is the optical design of the device. Displays are integrated into the eyeglasses to allow users to see the natural world and the virtual image simultaneously. The so-called optical combiner, which combines the real-world image with the virtual image generated by the display or projector, is at the heart of any AR device.

Already well known to the industry for decades, such combiners have not been suitable for everyday consumer use, especially because of their form. Waveguide technology offers a potential solution: flat substrates made of optical grade glass guide the light through the waveguide while simultaneously allowing light to pass through perpendicular to the waveguide's surface.

Many performance-defining parameters therefore depend on the waveguide material and its specifications, such as the refractive index, specific density, transmittance, homogeneity, flatness, warpage, et cetera.

To manufacture lightweight near-eye displays, AR devices use optical waveguides with diffraction gratings to guide light from a display by total internal reflection (TIR) into the human eye's view. Fig. 3 shows a scheme of the optical gratings used as light couplers. The small input grating in the waveguide diffracts the light coming from a light engine (or projector) into the eyeglass. The light is diffracted in the viewer's direction at the out-coupler grating. With uniform illumination of those out-coupling gratings, the structure depth increases with the traveled light distance in the waveguide, also named 'leaky gratings'.

There are various different designs of coupling gratings: one type is the so-called surface relief grating (SRG). Within this group, the gratings are classified into blazed gratings, binary gratings, analog gratings, and slanted surface relief gratings. Slanted gratings suppress higher diffraction orders and thereby maximize the light yield. Variation of the slant angle is desirable to achieve a high FOV, but is a certain challenge.

Different ion beam technologies are used to produce slanted surface grat-

ings depending on whether a constant or varying angle is required.

Reactive ion beam etching to manufacture SRGs

In the first step, a resin mask or pattern is created on a glass substrate by photolithography. The mask is used to structure an intermediate metal mask or the glass directly.

Full substrate processing by reactive ion beam etching (RIBE) is ideal for creating surface relief gratings with constant slant angles. Introducing reactive gases into the etching process makes it possible to control the selectivity of different surface materials and enhances the etch rate. The substrate can be tilted to etch slant angles as flat as 60° (Fig. 4). On top of the substrate material is a chromium mask, which defines the grating structures (Fig. 5).

Crucial parameters for the RIBE process are the selectivity between mask and substrate and the control of the grating geometry, particularly the side wall angle and bottom shape. Using different etching gases can control the degree of anisotropic etching behavior, which ultimately defines the resulting geometry of the gratings. Reactive gases can be introduced into either the ion beam source or the chamber via a gas ring. The ability to independently control ion energy and ion current is also used to adjust the slant geometry and selectivity.

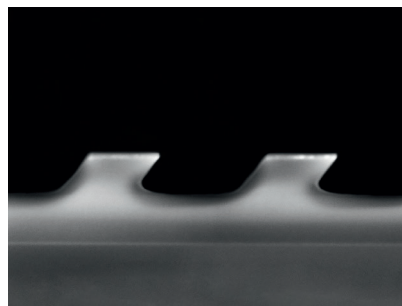
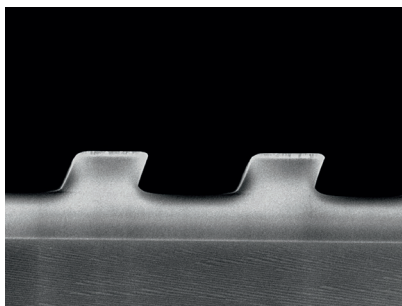


Fig. 7 REM pictures of slanted relief gratings with a small aspect ratio, etched with an angle of incidence of 20° (l) and 40° (r)

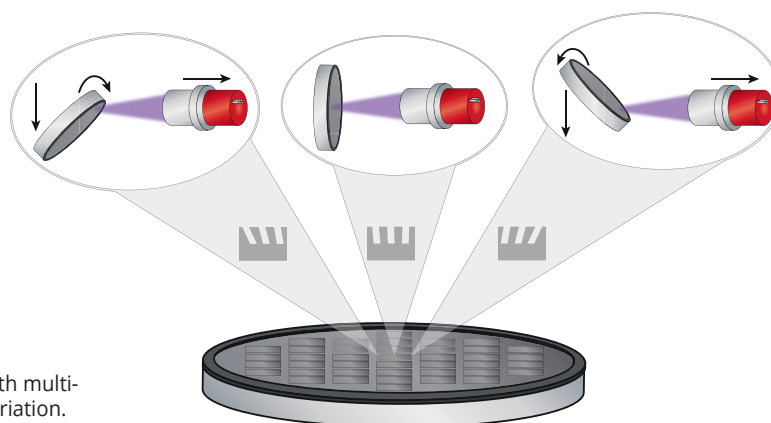


Fig. 8 Schematic of substrate with multiple SRG with depth and angle variation.

Another advantage of the reactive manufacturing process of surface relief gratings shows up in the need for the final device to have a wide FOV. The critical angle for total internal reflection limits the shallowest angle under which light may travel within the waveguide. The critical angle is smaller for high refractive index materials, and the FOV is bigger. That is why high refractive materials with refractive indices >2 will not be etched with standard gases like those used for quartz etching but with adapted mixtures and recipes. These unique capabilities to control the gas mixture, ion energy and ion current, substrate angle, and even the substrate temperature make RIBE the preferred technology for etching slanted relief gratings.

Variation of the slant angle is desirable to achieve a high FOV, yet somewhat challenging. Ion beam trimming (IBT), a well-established technique in the semiconductor industry to locally modify a given substrate's thickness and achieve the required target topography, is ideal to create surface relief gratings with varying slant angles and etch depths. IBT uses a focused broad beam of positively charged ions to etch material locally off the glass substrate by ion bombardment. An ideally shaped ion beam ensures sufficient lateral resolution and a high throughput. The ion beam meanders across the substrate surface during trimming. The amount of material removal can be precisely adjusted by altering the local dwell time.

Reactive ion beam trimming (RIBT) has been adapted to fabricate surface relief gratings with varying slant angles and trench depth. The optically transparent substrate is covered with a hard mask that provides the basic grating geometry, such as period and duty cycle. Then, the trenches are created using localized ion beam etching. Vary-

ing the ion irradiation dose using dwell time variations sets the local trench depth. The angle of incidence of the ion beam into the substrate directly affects the resultant slant angle. It can be varied independently of the dwell time, providing the unique ability to achieve a continuous variation of the slant angle across one die.

Additional reactive gases are added to the ion beam source to avoid redepositing the sputtered trench material onto the grating side walls. The plasma activation of the reactive gases leads to a chemical and physical etching of the substrate material, which helps to increase throughput, material selectivity, and the trench angles of patterned surfaces.

The choice of the process parameters, e.g., process gas composition and ion energy, allows the selectivity between the hard mask and the optical material to be tuned so that high aspect ratio trenches are possible while keeping the hard mask thin. This avoids any shadowing of neighboring structural features.

Direct structuring of waveguides vs. structuring of master stamps

The slanted gratings can be etched either directly into the waveguide or into a master stamp (mold) that is used to produce the AR/MR display via nano-imprint lithography (NIL). For NIL, the master stamp is pressed into a polymer to replicate the pattern. These NIL master stamps therefore have the same pattern as the resulting optical gratings. The masters are manufactured by a pattern transfer from a masked substrate.

As described earlier, photolithography creates a resin mask or pattern on a substrate. In the next step, this mask is used to directly structure an intermediate metal mask or substrate by reactive ion beam etching (RIBE). The incident angle of the ions and the slant angles can be defined by tilting the substrate relative to the ion beam. Changing the ion energy, beam current density, and the reactive gas inlet can influence the ratio between anisotropic and isotropic etch behavior. It is therefore possible to design parallel side walls and define the



Fig. 9 scia Trim 200 ion beam trimming system for the production of slanted gratings on 200 mm wafers

bottom shape of the gratings. To achieve a wide field of view, variation of the slant angle is desirable, but somewhat difficult to reach across a single die using nanoimprint lithography or by filling in a mold and subsequently curing the grating material. The grating ridges in the mold or the grating itself may break during separation because of the opposite directions of the trenches. Using IBT, the thickness of a functional layer on a given substrate can be modified to achieve the desired target topography and to fabricate SRGs with varying slant angles and trench depths. Varying the ion irradiation dose through dwell time adjustment will define the local trench depth. The angle of incidence of the ion beam into the substrate directly affects the resultant slant angle. It can be varied independently of the dwell time, providing the unique ability to achieve a continuous variation of the slant angle across one die. RIBT is used to manufacture NIL master stamps and avoid re-deposition of the sputtered trench material onto the grating side walls. The RIBT technology allows the grating angle to be freely tuned from -45° to 45° over an area of 30×30 mm and

the etching depth at certain positions on the substrate (Fig. 8).

Conclusion

The manufacture of surface relief gratings is crucial to nanostructuring today. Their applications range from laser mirrors to the manufacture of waveguides for mixed and augmented reality. Slanted SRGs are used as in and out-coupling gratings, etched either directly into the waveguide or into a NIL master stamp.

Scia Systems offers industry-approved solutions to meet customers' needs for high-quality waveguide or master stamp patterning. The systems

offer high-precision surface etching or trimming of wafers without material limitations. Designed for high-volume production, the equipment has a throughput and maintenance optimized layout with a semiconductor cassette-handling robot that accommodates all standard wafer sizes.

*

I would like to thank all colleagues at Scia Systems who contributed for their great work, especially Dr Mandy Göring and Robert Metzner for the process development of reactive ion beam etching and reactive ion beam trimming.

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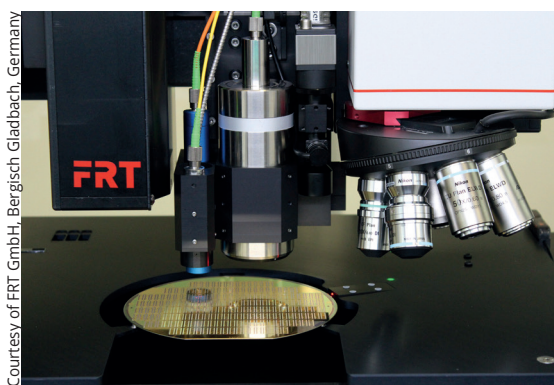


Optical Measurement Technology

Early view – read the full article in the PhotonicsViews E-Special 1/2025

Beginning to see the light

Calculating the reflectance of semiconductors with vias



Investigation of structured semiconductor surfaces with multisensor technology

The reflectance of a semiconductor wafer changes if vias or trenches are etched into the semiconductor. We present a rigorous far-field model that allows to calculate the reflectance

under consideration of the geometrical properties of the via as well as possible transparent coatings on the wafer surface or transparent fillings in the via. For this the wafer is divided into units with a single via or trench. Each unit can further be divided into regions, the wafer surface region and the via or trench region. Transparent coatings or transparent fillings of the via are considered by simulating the reflectance of each region as the reflectance of a layer stack.

The proposed rigorous model in the far-field is originally intended to be applied on semiconductor surfaces with vias to simulate broadband reflectance spectra of such structured surfaces. The main component of the model is the simulation of the reflectance

of each region by the reflectance of a layer stack. By this way, we obtain a large variety of similar structured surfaces, since only thickness of the layers and their refractive indices are necessary to calculate the reflectance of each region. The effects caused by diffraction, scattering, inclined walls, or a curved via bottom are the same also for other materials.

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Addressing transferability and stability in Raman spectrometers

How to design instruments for industrial environments

Bjarke Rose



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The invention of lasers has enabled the widespread use of Raman spectroscopy in scientific laboratories, and recently Raman spectroscopy has been applied in industrial environments as well. Based on Ibsen Photonics' experience as an OEM supplier of Raman spectrometers for various applications, this article reviews key concerns that must be addressed when designing a Raman spectrometer for industrial applications.

Raman spectroscopy was first demonstrated experimentally in 1928 by C. V. Raman and K. S. Krishnan. The technique relies on the inelastic scattering of monochromatic light in a sample and is often a complementary technique to infrared absorption spectroscopy.

In Raman scattering, an incident photon either gains or loses energy by interacting with intermolecular vibrations within a molecule. The change in energy corresponds to a blue or red shift in the wavenumber of the incident light. Because the vibrational modes of a molecule are unique to each molecule, the wavenumber shifts, i.e. the Raman spectrum constitutes a unique fingerprint for the molecule.

The invention of lasers in the 1960s enabled Raman spectroscopy to become a common tool in many scientific laboratories. During the past two decades, Raman spectroscopy has also found usage in more demanding industrial environments.

A Raman instrument typically consists of four fundamental subsystems: a laser, a probe, a spectrometer, and a software model, as shown in Fig. 1. The laser provides monochromatic light that illuminates the sample. The probe ensures that the laser light is focused on the sample and that the scattered light from the sample is collected and focused on the spectrometer. Generally, the probe includes delivery and collec-

tion optics, as well as several optical filters. The spectrometer detects the Raman spectrum, i.e. the light intensity versus wavenumber shift.

The scattered Raman light is usually weak and buried in background light. The software model must therefore include preprocessing to remove this background and any other undesired spectral artifacts. Differentiation between various molecular structures is often achieved through multivariate statistical data analyses – referred to as chemometrics models. These models correlate small differences in spectral features with differences in molecular structures.

A chemometrics model first involves calibration using a reference set of

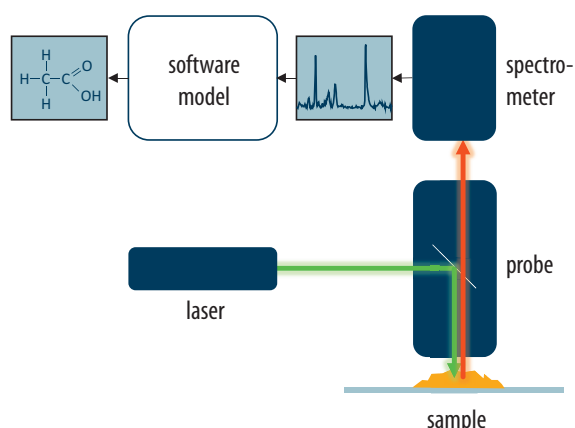


Fig. 1 Schematic view of a basic Raman system consisting of a laser, a probe, and a spectrometer

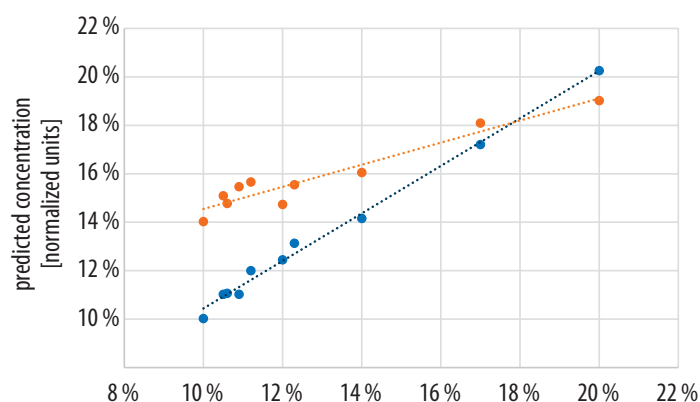


Fig. 2 Model predictions for two instruments versus measured concentrations. Blue marks: instrument providing acceptable results, orange: instrument providing incorrect results

samples with known concentrations, measured by a gravimetric method for instance. Then the model is used to predict the results for unknown samples. The better the original reference samples represent the variability of the unknown samples, the better the model predictions are.

Moving Raman spectroscopy out of the lab

A scientific laboratory often owns one or more highly advanced, general purpose Raman spectroscopy systems. The instruments are operated by skilled personnel, and software models are developed and refined by scientific experts. However, the operating conditions change when a Raman spectroscopy system is to be used in an industrial environment such as on the factory floor.

First of all, the instruments are often purpose-made to measure only a few well-known types of samples. An exam-

ple of an application would be the outgoing quality check of the amount of active ingredients in pharmaceutical tablets. The instruments could be operated close to 24/7 by non-experts and just have a simple and intuitive interface and a minimal amount of daily calibration.

Industrial Raman instruments can also be exposed to harsh environmental conditions such as temperature variations and vibrations. It is therefore important that the instruments are designed to be robust against such environmental conditions.

In contrast to the situation in a scientific laboratory, it is common that many identical instruments are used on the various production lines and/or factory sites. Also, the instruments must be easily replaceable for maintenance and repairs.

Transferability

As mentioned earlier, the interpretation of measured raw Raman spectra

often requires chemometrics models. Model transferability means that the same result – within acceptable limits – is obtained when the same sample is measured with different Raman instruments. Since industrial applications of Raman spectroscopy involve the same measurement by many similar instruments that all operate with the same global chemometric model, transferability becomes hugely important.

Ideally, the Raman systems should all be identical, but there will inevitably be slight variability between the individual instruments due to small differences in the parts used. Another contributing factor to variability is the operating conditions of the instruments. These variations can be accounted for during model calibration to some extent, but to account for all possible variations would require an impractically large set of reference Raman systems and operating conditions. Typically, five to

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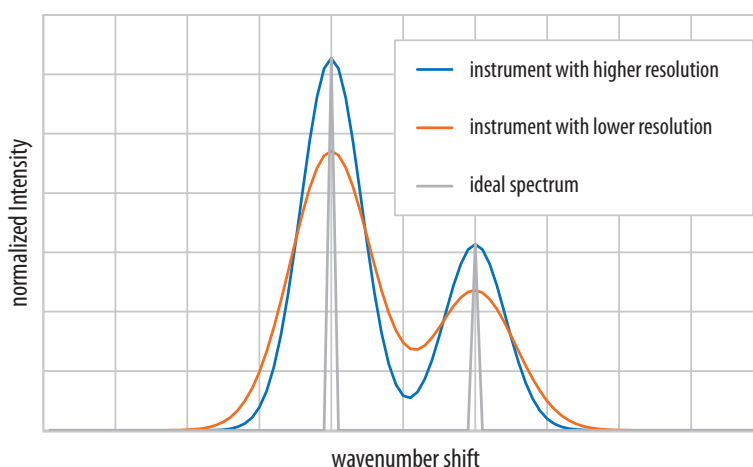


Fig. 3 Simplified Raman spectra illustrating the effect of finite resolution of the instrument

ten reference instruments are used to build a chemometrics model.

Wavenumber calibration, spectral resolution, intensity calibration, and photometric linearity are all instrument parameters that can influence the transferability of a chemometric model. Fig. 2 shows an example of sample concentration measured with two different Raman instruments. The x-axis represents the true concentration of the reference samples measured by a gravimetric method. The blue marks are predictions based on an instrument sufficiently similar to the reference instruments used for building the model, with the results in line with the measured values. The orange marks, however, are predictions made using an instrument substantially different from the reference instruments, predicting significantly incorrect results.

Spectrometer resolution

Let us examine one of the key parameters influencing model transferability: spectrometer resolution. Raman spectroscopy generally requires high-resolution spectrometers to resolve closely spaced peaks. Resolution is therefore a particularly important parameter for Raman spectrometers.

Fig. 3 shows a simplified plot of an ideal Raman spectrum with two peaks measured using two different instruments. One instrument has a higher resolution, while the other has a lower resolution. The effect of finite spectrometer resolution is that the peaks are broadened. The poorer the resolution, the wider the peaks, and the lower each peak.

The diagram clearly illustrates how resolution influences the overall shape of the spectrum. Furthermore, Fig. 3 shows resolution peaks for a spectro-

meter with symmetrical resolution peaks. However, it is not uncommon for the resolution peaks to be asymmetric. If the asymmetry varies from instrument to instrument, it can pose a further challenge for the chemometrics model to correctly interpret the spectrum.

How to control instrument variability

Instrument variability arises from the combined effect of many small variations in the components used to build the spectrometer. These variations stem from the tolerance specifications of the components. The tighter the tolerances, the higher the cost, so tolerances should always be balanced against the overall cost target of the Raman spectrometer. For example, the resolution of a spectrometer is influenced by the tolerances in the focal lengths of lenses and optomechanical mounts as well as mounting tolerances during assembly. To achieve model transferability in volume production, it is crucial that the spectrometers are sufficiently similar. First and foremost, the key to this is designing the spectrometer to be as insensitive as possible to variations in its components and assembly methods. Secondly, precise alignment of each spectrometer during manufacture can maintain parameters such as resolution and peak asymmetry within certain limits. Alignment involves adjusting the position of components such as lenses while monitoring an instrument parameter – like resolution and peak asymmetry – to compensate for unit-to-unit variations.

A good spectrometer design therefore requires an in-depth tolerance analysis of the entire system to identify the components that influence instrument variability the most. Com-

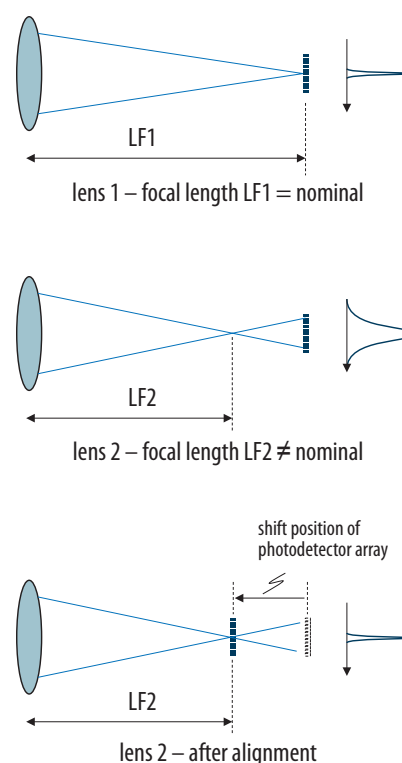


Fig. 4 Illustration of how differences in focal length between different lenses can be compensated by adjusting the position of the photodetector array

pensating alignment methods should be built into the design based on the outcome of the tolerance analysis. This process requires a deep understanding of the nature of volume production of optomechanical subsystems to ensure a good design for manufacture. Fig. 4 schematically illustrates a simplified example of alignment to achieve the same resolution for two instruments. The top drawing in Fig. 4 shows a situation where the lens used has the nominal focal length, which is the focal length for which the instrument was designed. The middle and lower draw-

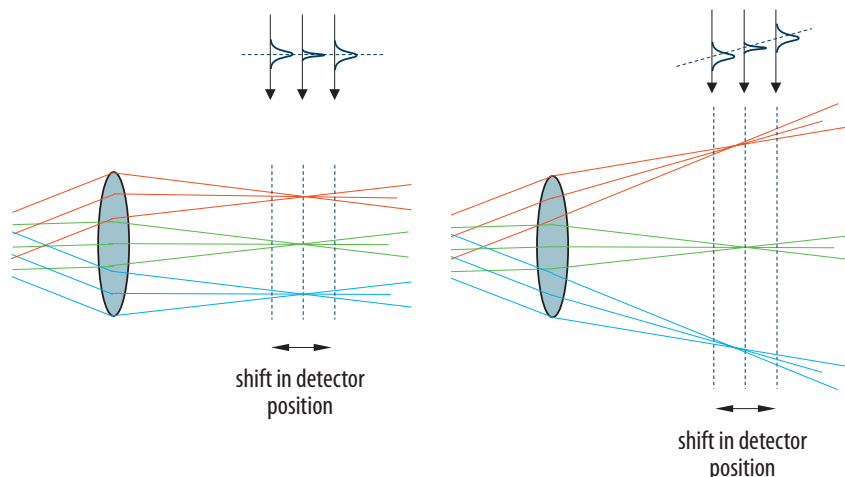


Fig. 5 Center wavelength shift sensitivity of the design: (l) telecentric design with no change in center wavelength due to detector displacement; (r) non-telecentric design with center wavelength changes due to detector displacement

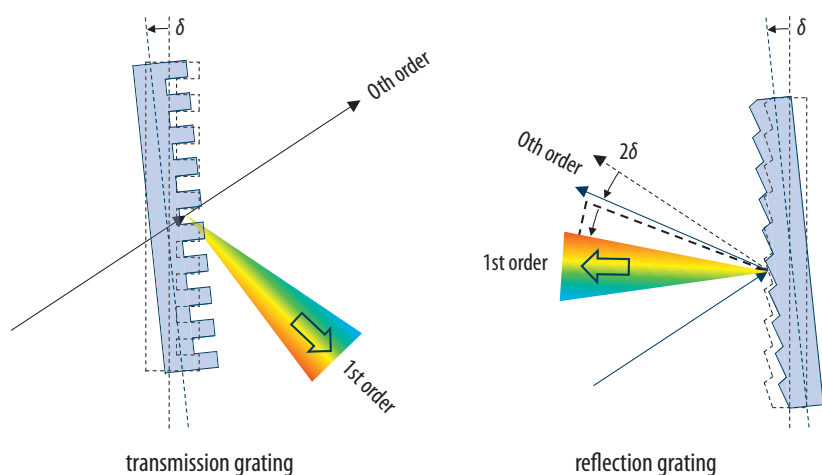


Fig. 6 Illustration of sensitivity to angular displacement of diffraction gratings: (l) transmission grating is not sensitive to small angular displacements; (r) reflection grating is sensitive to angular displacement

ings in Fig. 4 depict a situation where the focal length of the lens is too short, causing the beam to be out of focus on the photodetector array. By moving the photodetector array to the focal point of this lens, the resolution is restored to the desired narrow tolerance.

Environmental stability

Instruments used in industrial settings can be exposed to a range of environmental influences that are not present in a laboratory. For example, the ambient temperature and humidity may vary due to changes in weather conditions or the presence of nearby machinery generating heat and/or moisture. Additionally, if the instrument is mounted on another machine it may experience vibrations from that machine.

Variations in the ambient environment can have detrimental effects on Raman instruments. The different components of the instrument are made from various materials, such as glass, polymers, and metals. These materials expand and contract differently with temperature changes, which can lead to performance degradation of the spectrometer or even permanent damage to

the instrument. Similarly, vibrations may cause components inside the spectrometer to shift positions, resulting in performance degradation. In the worst case, a component such as a lens might completely detach from its mount, rendering the device inoperative.

How to control instrument stability

The key to maintaining instrument stability is to design it to be as insensitive and robust as possible against environmental influences. In general, it is preferable to design the spectrometer without any moving parts, such as rotating diffraction gratings or adjustable slits. This is because motor-driven components wear out over time and are susceptible to vibrations. For this reason, fixed-grating, diode array-based Raman spectrometers are preferred over those based on scanning gratings.

The optical design of a spectrometer can significantly influence its sensitivity to temperature variations. For instance, the distance between the last lens in the spectrometer and the photodetector array may change due to thermally induced expansion and

contraction of the metal mounts. Fig. 5 depicts two different design options: a telecentric and a non-telecentric design. In the telecentric design, the shift in detector position does not alter the focal point position on the detector array but does broaden the resolution peak. The focal point corresponds to the center wavelength of a peak measured by the spectrometer. In contrast, in a non-telecentric design, the shift in detector position leads to a shift in the focal point position and, consequently, the center wavelength. Additionally, the shift in center wavelength varies for different parts of the spectrum.

Another aspect of the optical design that can influence the sensitivity to component displacement is the choice of transmissive rather than reflective optics. Fig. 6 illustrates an example of this, namely the angular sensitivity of a reflection grating versus a transmission grating. An angular rotation can be the result of vibration or another asymmetric mechanical disturbance on the grating mount. The reflective grating acts like a mirror, which means that an angular rotation of one degree results in an angular shift of the dif-

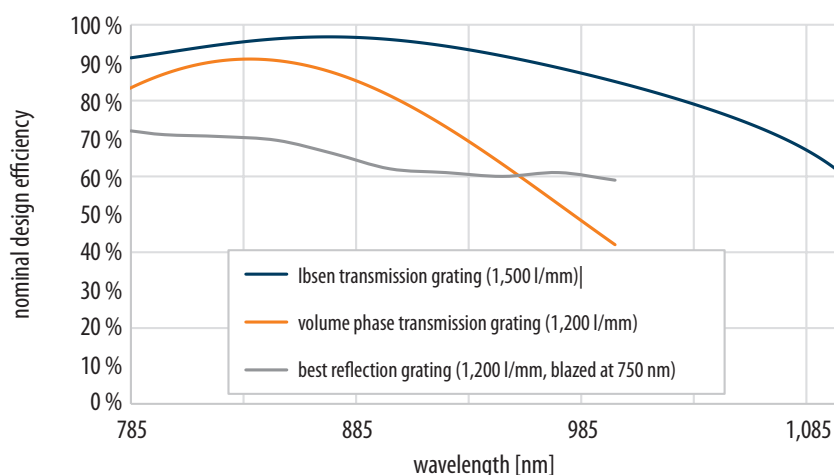


Fig. 6 Comparison of diffraction efficiency for typical diffraction gratings

fracted grating orders by two degrees. The consequence is that the spectrum shifts on the detector array. In contrast, the grating orders of a transmission grating do not rotate with small angular rotations of the grating. This exemplifies why transmission optics are less sensitive to rotational changes than reflection optics.

High-resolution, compact Raman spectrometers typically require gratings with a high groove density and diffraction efficiency as close to 100 % as possible. Transmission gratings with a high groove density can offer nearly 100 % polarization-insensitive diffraction efficiency. In contrast, blazed reflection gratings with high groove densities generally provide an average polarization-dependent efficiency of around 60 %. See Fig. 7 for a comparison of typical gratings used for a 785 nm laser Raman spectrometer. This throughput advantage further highlights the benefit of using transmission gratings over reflection gratings.

Summary

As Raman spectroscopic instruments find use in industrial settings, instrument-to-instrument transferability and robustness against external environmental influences become critical. Although chemometric models can correct for some level of instrument variability, it is still important to maintain certain instrument characteristics, such as peak resolution, within specific boundaries. This can be achieved by carefully designing the spectrometer and using assembly methods based on a comprehensive tolerance analysis. Furthermore, active alignment of each instrument is essential to obtain minimal unit-to-unit variation.

Environmental factors like temperature changes and vibration can degrade the performance of a Raman spectrometer. To reduce its sensitivity to such external disturbances, the spectrometer should be designed with no moving parts and a tolerance for component displacements. Furthermore, the use of transmission optics rather than reflective optics helps to improve overall throughput and reduce sensitivity to environmentally induced displacements.

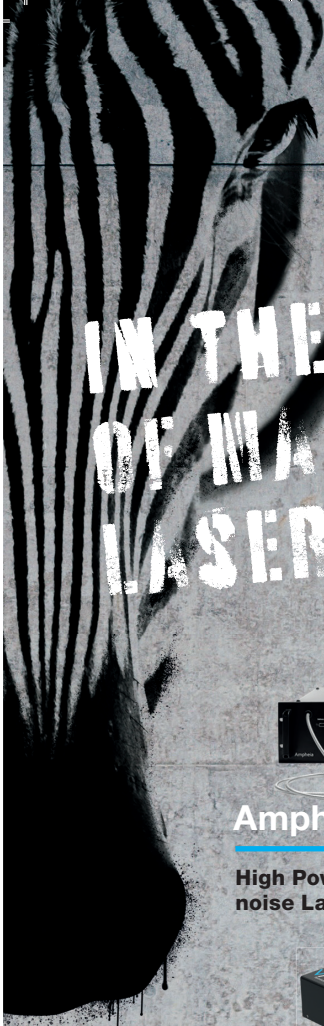
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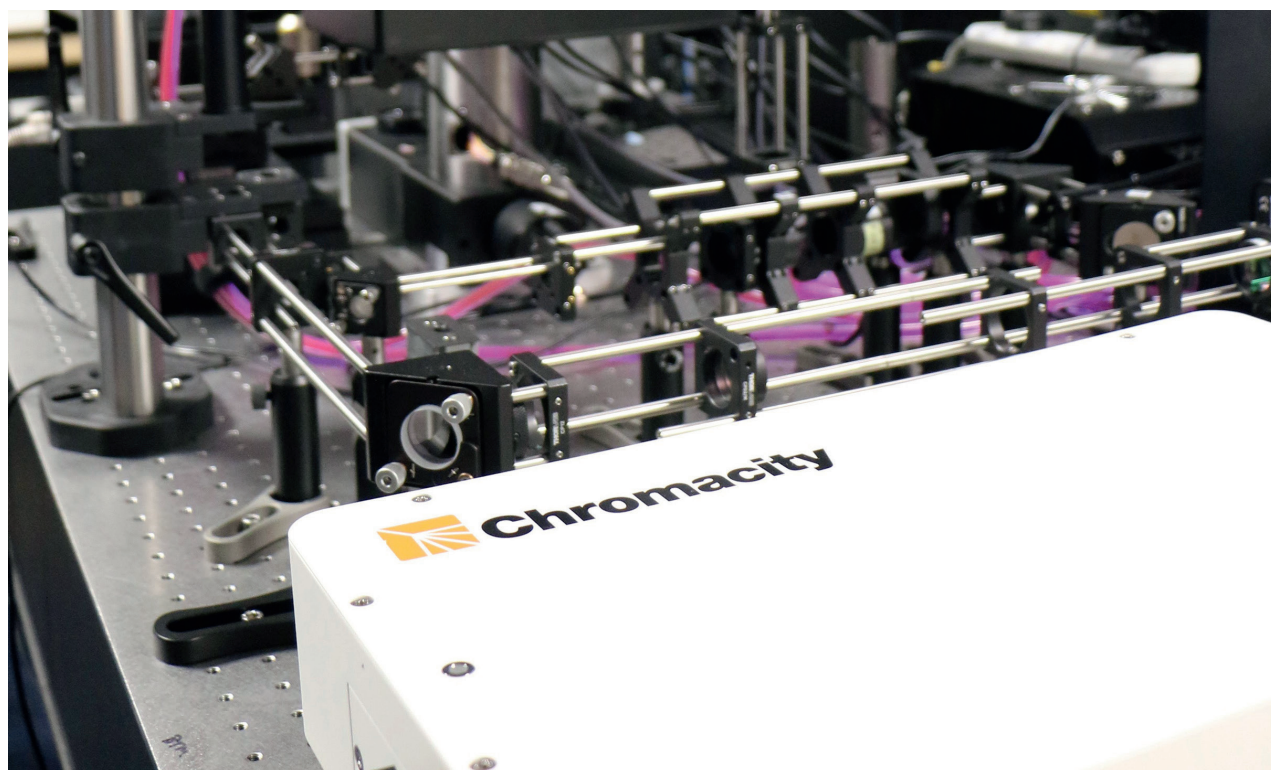


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Quantum spectroscopy using entangled photons

Fiber lasers improve the efficiency and reliability of entangled photon creation

Wojciech Gora



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The field of quantum optics is undergoing massive growth, which is enabling a host of new applications within the field. The quantum nature of light allows us to push the limits of various techniques including, but not limited to, spectroscopy, interferometry, sensing and imaging. At the heart of these is a need for a reliable source of entangled photons. The quantum revolution is underpinned by ultrashort pulse duration lasers, and especially fiber lasers. Ultrafast fiber lasers provide reliable ultrashort pulse durations at an unprecedented price point.

Quantum physics has enjoyed a significant rise in popularity over the last two decades. The quantum nature of light allows various optical measurement techniques to be extended that were previously thought of as being constrained by classical limits. The evolution of quantum physics techniques is closely aligned with the evolution and emergence of novel laser sources, which underpin the growth of new applications in the quantum universe.

One of the methods that benefits from quantum effects is spectroscopy, where matter is detected based on either the time or the frequency response of the material.

Conventional spectroscopy that uses the classical nature of light detects a specimen response with time delays and/or frequency changes. It is possible to enhance the capabilities of a spectroscopic system by using the fluctuations of quantum light.

One of the benefits of using the quantum description of light is the fact that the signal intensity scales differently when compared to the classical approach. When the classical two-photon effect is considered, the intensity of the signal scales quadratically. As a result, quite high intensity light is required to achieve an acceptable signal-to-noise ratio. However, when employing quantum spectroscopy, and a pair of entangled photons is observed

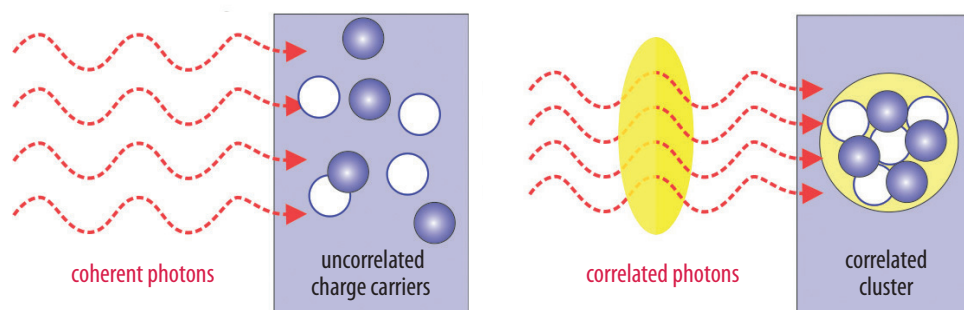


Fig. 1 Classical (l) vs. quantum spectroscopy: in quantum spectroscopy, photons are correlated, creating clusters, whereas photons are not correlated in classical spectroscopy [1]

within a low intensity light beam, the process is linear when regarding the pair. As a result, it is possible to achieve a suitable signal-to-noise ratio even at low intensities [2].

Different methods that underpin the field of quantum science will be discussed in this article, specifically quantum spectroscopy. This is a new and exciting application of quantum light at the forefront of technological progress and one of the first practical real-world uses of quantum photonics.

Entangled photons

The emergence of new applications within the quantum universe is directly connected to the improved ability to efficiently generate a stream of entangled pairs of photons. Entangled photons are pairs of light quanta created in such a way that the quantum state of one cannot be described independently and both photons are required to fully describe the current state. Knowing the physical properties of one entangled particle, such as polarization, momentum, position, or spin allows perfect correlation to the other. This phenomenon is still correct even at a vast distance, and was famously reported by Albert Einstein as a “spooky action at a distance”.

Quantum entanglement finds uses in some revolutionary fields such as quantum computing, quantum cryptography, quantum imaging, and sensing. A reliable way of creating entangled photons underpins all of these applications. In the next section, different ways of creating entangled particles will be reviewed, and specifically how ultrafast laser technology is a key enabler.

Creating entangled photons

There are several methods of creating pairs of entangled photons, such as spontaneous parametric down-conversion (SPDC), spontaneous four wave mixing (SFWM) and quantum

dots. The availability of ultrafast lasers capable of generating very high peak powers suitable for SPDC has significantly contributed to the ease of access to methods of generating entangled photons. Fiber lasers are capable of reaching the required high energy densities in a reliable and cost-effective manner.

Spontaneous parametric down-conversion

The most widely used method of generating entangled photons is spontaneous parametric down-conversion. SPDC is a nonlinear process where one photon (pump) is converted into two photons (signal and idler). This interaction conserves momentum and energy, which leads to the two entangled photons splitting the energy of the pump photon as well as splitting the momentum of the original photon.

The most common SPDC setup uses a high-intensity laser beam directed at a nonlinear crystal, such as a PPLN (periodically poled lithium niobate) or a BBO (beta-barium borate) crystal. The majority of photons will go through the crystal unaltered, but some will undergo SPDC. The pair of entangled photons can have different paths and have a cone-type trajectory. Ultrafast fiber lasers capable of reliably delivering ultra-short pulses, such as the Chromacity 1040 laser, are ideal candidates for this application. This laser delivers 100 fs pulses with a peak power of 353 kW, and is commonly used to pump the nonlinear crystal.

Another laser type that opens up a wider range of wavelengths is an optic parametric oscillator (OPO) laser source, such as the Chromacity Auskerry and Haskeir lasers. The tuneability and high peak powers offered by the picosecond OPOs along with their reliability and compactness make them ideal for accessing new wavelength bands.

Spontaneous four-wave mixing (SFWM)

Another method used to generate pairs of entangled photons is spontaneous four-wave mixing. In SFWM – which is a third-order nonlinear process – the two photons (pump) combine to create a different pair of photons in a phase-sensitive process. One of the outgoing photons is called the ‘idler’ and the other the ‘signal’. The nonlinear process often uses an optical fiber as the nonlinear medium. The energy and momentum of the incoming versus outgoing photons is maintained during the process.

Quantum dots

Quantum dots are semiconductor nanocrystals or small particles with a diameter between 2 and 10 nm [3]. A high-intensity laser can be used to excite a biexciton in the quantum dot, and it emits a pair of entangled photons as it relaxes to the ground state [4]. This approach offers the potential to control the properties of the emitted photons (e.g. their wavelength and polarization) and has a higher efficiency generation of entangled photon pairs [5]. This capability makes quantum dots an attractive candidate to be used in quantum integrated circuits.

Company

Chromacity

Chromacity is active worldwide in the design, development, and manufacturing of advanced ultrafast-pulsed fiber lasers. Based in Edinburgh, UK, the company specializes in fixed wavelength femtosecond and picosecond optical parametric oscillator-based tunable laser systems (OPOs). These lasers are simple to use, with no specialist support required to operate them – you turn them on, configure and use. These compact, air-cooled devices offer unrivalled long-term pulse stability without the need for ongoing maintenance.

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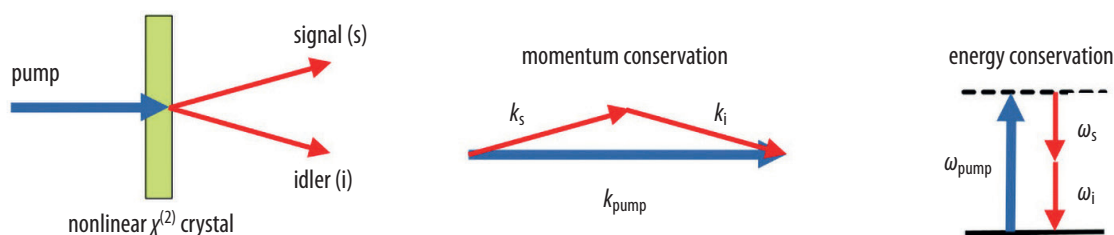


Fig. 2 The diagram for spontaneous parametric down-conversion

Quantum sensing applications

The use of quantum light enables measurements to be taken at very low light intensities. This is a crucial benefit, allowing the analysis of samples that are highly sensitive to high-intensity light fields. In addition, each quantum-entangled pair of photons can have different energies or wavelengths. This enables visible photons to be detected while obtaining information from the photon at longer wavelengths, without the need for direct detection. This characteristic significantly opens up the parameter space for potential applications; current studies include biological microscopy [6].

Quantum imaging applications

Using quantum optics allows the resolution of imaging to be pushed beyond the shot-noise limit. One of the areas that benefits from this is quantum lithography, where the use of entangled light enables the creation of smaller structures than the Rayleigh limit would suggest [2]. Another technique that benefits from the quantum property of light is ghost imaging. In this scenario, a beam consisting of pairs of entangled photons is used where one beam propagates through the object and the other beam does not [7]. Information on the object can be obtained from the wavelength that did not interact directly with the object.

Quantum interferometry

Optical interferometers have been crucial tools used for precise measurements over the last few decades. When con-

sidering interferometry in the quantum realm, the classic interferometers such as the Mach-Zehnder or Michelson cannot be used. That has led directly to the development of the N00N state and Hong-Ou-Mandel (HOM) interferometers [8]. Quantum interferometry relies on fundamental principles such as second quantization. As a result, their behavior is inexplicable using classical analysis techniques [8].

A lot of the methods that have been developed within the field of quantum interferometry are underpinning applications in other fields, such as quantum optical coherence tomography (Q-OCT), where a fourth-order interferometric scheme is used.

Applications of quantum spectroscopy

The possible applications of quantum spectroscopy cover a lot of different fields:

- Sub-shot noise spectroscopy, where low-concentration samples and weak signals can be measured. The levels of those would not be sufficient for classical spectroscopy
- Quantum two-photon absorption spectroscopy – enables the measurement of light-sensitive samples with a relaxed requirement for light intensity
- Quantum optical coherence tomography – when compared to classical OCT, Q-OCT is not sensitive to dispersion, even in a highly scattering media
- Quantum-enhanced Raman spectroscopy.

Quantum optical coherence tomography (Q-OCT)

The benefits of quantum light-enabled imaging of biological samples (in this example, an onion skin sample) arise from the need for very low power levels, and the possibility of use in highly scattering media. Experiments have shown that measurements can be done with an average power of approximately 0.5 pW. The benefit of using Q-OCT versus a conventional OCT is due to the dispersion behavior: classic OCT employs a broadband light source, which leads to a drop in the depth resolution of the measurement; Q-OCT is not limited by the same boundaries and is significantly less sensitive to light dispersion because it does not use a broadband light source.

Quantum-enhanced Raman microscopy

Stimulated Raman scattering (SRS) microscopy is an excellent tool for label-free imaging of samples prone to photo damage. Use of the Raman effect is based on the measurement of Stokes photons that are scattered from the sample, which is pumped by a light source. The frequency shift between the pump and scattered photons can be measured, which enables the tested material to be identified. To overcome the photo-damage limit of the investigated specimen, a quantum light source can be used where a squeezed state of light suppresses any shot noise [9] and so allows a lower light intensity to be used while still maintaining good signal-to-noise. The use of the quan-

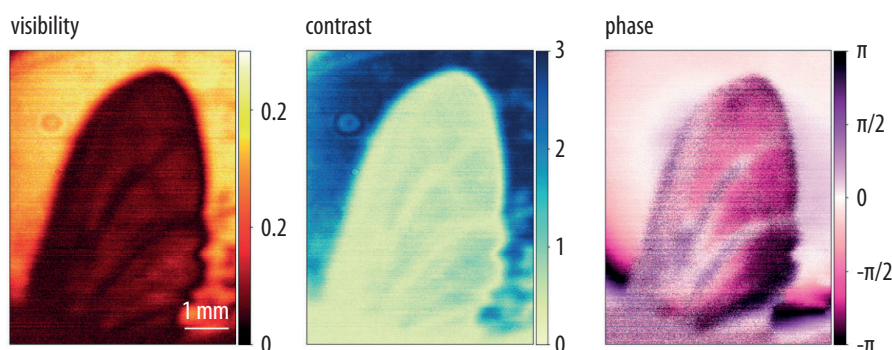


Fig. 3 A fly wing was detected at 808 nm and probed at 1,559 nm [7]

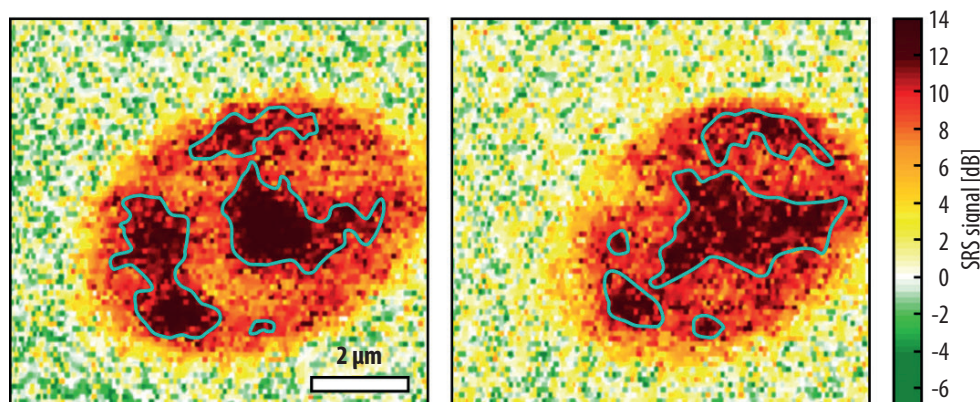


Fig. 4 Quantum image of organelle motion [9]

tum nature of the light allows lower light levels to be used for successful measurement.

Molecular and material analysis / detection

The quantum nature of light can be used for detection schemes of molecules such as gases. The use of entangled photons at two different frequencies enables the gas to interact with light at a wavelength corresponding to one of its absorption features while the entangled light at a different wavelength is detected. This permits detection to be shifted from one region of the spectrum to another where the detector technology might be substantially better.

An example of this can be found in [10], where a scheme for methane detection is presented. Methane has strong absorption bands in the mid-infrared, but inherently noisy and expensive detectors are required for detection. The benefit of using the two-color quantum method with entangled photons shows that it is possible to use visible and near-infrared detection methods while still taking advantage of the stronger mid-IR absorption features. This reduces the cost, but also benefits from the significant development of detection methods for this wavelength band. As a result, the methane detection scheme presented here enables methane to interact at mid-IR wavelengths, whereby a short IR photon measurement is employed. This detects low concentrations of methane while maintaining high precision.

Conclusions

Quantum physics is a field that has undergone significant progress over the last ten to twenty years. The benefits of the quantum nature of light are being used more frequently. Techniques known for using the classical nature of light, such as interferometry and spec-

troscopy, can be radically improved by using quantum technology. The progress made can also be attributed to ultrafast laser source development. Laser technology underpins quantum science, acting as a starting point in the creation of entangled pairs of photons. The evolution of lasers, especially fiber lasers, has increased efficiency and reliability at a lower price point, enabling easier access to the technology. The symbiotic relationship between the fields will have to continue so that new boundaries can be pursued across all applications.

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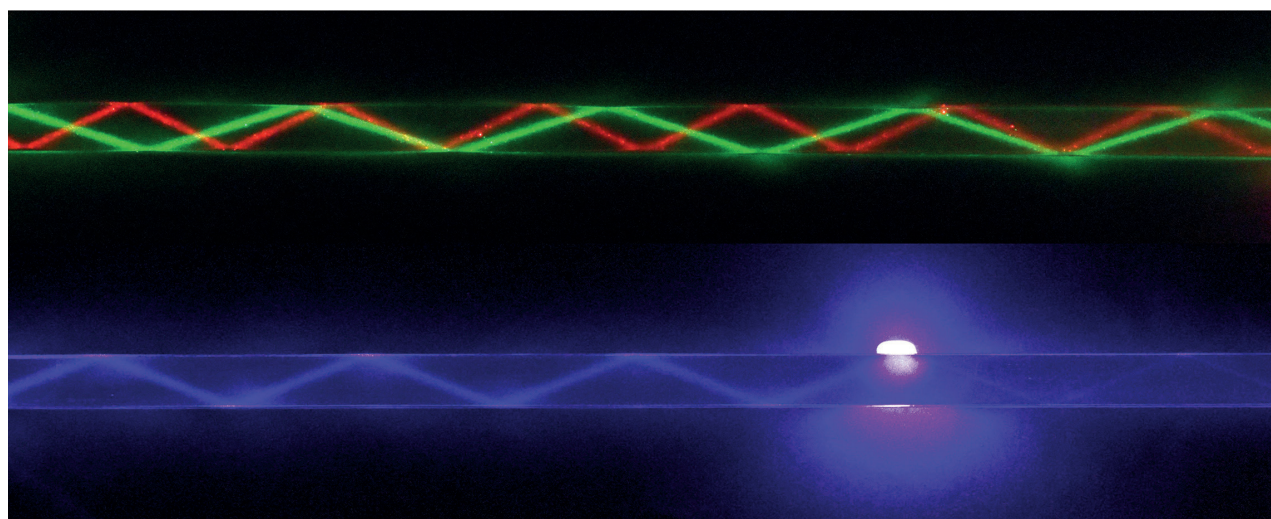


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Future touchscreen disinfection by integrated UVC LEDs?

A quartz plate and UVC LEDs enable fast automatic touchscreen disinfection

Martin Hessling, Kilian Noller, and Ben Sicks



Source all images: Technische Hochschule Ulm

The application of touchscreens in the public and healthcare sectors is increasing worldwide. Their use by different people allows the unintentional spread of pathogens. The combination of UVC LEDs and a quartz plate appears to make it possible to rapidly and automatically disinfect touchscreens between different users without harming the human operator.

All touchscreens are microbially contaminated

The number of touchscreens is increasing at a steady rate on a global scale, with a notable presence in all areas of life. The transfer of microorganisms from the fingers to touchscreens and vice versa occurs due to the fact that the skin and fingers are colonized by a variety of microorganisms, including

bacteria, fungi and viruses. A review of published studies on the microbial contamination of touchscreens revealed no instances of a completely germ-free device. At the very least, staphylococci have consistently been identified. The typical contamination level was in the order of ten microorganisms per square centimeter, although individual cases have been reported in which several hundred microorganisms per square centimeter were present [1]. Fig. 1 illustrates typical microbial contamination of an ATM, a ticket machine and an ordering device in a fast-food restaurant after five days of incubation.

The contamination of touchscreens can result in the transmission of infections, both in public settings and within healthcare facilities. To prevent this, touchscreens must be disinfected after every use. While manual application of chemical disinfectants is a potential solution in individual cases, it is not a

▲ Top: Multiple total reflection of two laser beams in a clean, thin acrylic glass layer. The light does not leave the glass. Bottom: Violet laser beam in 'contaminated' acrylic glass. When the beam hits the contamination (here: candle wax) the total reflection is distorted and the surrounding area outside the glass irradiated

viable option for larger-scale disinfection due to the high workload and consumption of disinfectants.

UVC irradiation of microorganisms, but not humans

Ultraviolet C (UVC: 100 – 280 nm) radiation emitted from lamps or light-emitting diodes (LEDs) has the potential to destroy the DNA and RNA of microorganisms, thereby disinfecting touchscreens. Nevertheless, it is very important to ensure that this radiation does not cause harm to humans. This can be achieved by fitting capacitive

Institute

Ulm University of Applied Sciences Institute for Medical Engineering and Mechatronics (IMM)

The IMM is involved in applied research and development in a variety of areas, one of which is the interaction between light and (micro-) biology. This includes radiation disinfection in the spectral range 200 – 700 nm and illumination during retinal surgery.

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Fig. 1 Contact agar plates were observed five days after sampling the touchscreens of an automated teller machine (ATM), a ticket machine at a railway station, and an ordering device in a fast-food restaurant. The mean initial concentration on these contact agar plates was approximately eight microorganisms or colonies per square centimeter.



touchscreens with a quartz glass front panel that is UV-transparent and into which the radiation from UVC LEDs is coupled from the side (see Fig. 2). The quartz plate functions as a light guide, employing the phenomenon of total internal reflection. In this idealized concept, the radiation coupled out in the direction of the human user is minimal, yet microorganisms on the front screen are still irradiated. In the context of wave optics, the microorganisms are exposed to the evanescent field, whereas in geometric optics, there is no total reflection at the site of microbial contamination. However, the UVC rays pass through the microorganisms and destroy them when absorbed by their DNA and RNA.

Disinfection of contaminated quartz plates

To evaluate the efficacy of this disinfection approach, five distinct bacterial strains were selected that represent genera that are among the most frequently identified on touchscreen surfaces [1]. These were *Staphylococcus carnosus* (*S. carnosus*), *Acinetobacter kookii* (*A. kookii*), *Escherichia coli* (*E. coli*), *Enterococcus mundtii* (*E. mundtii*) and *Micrococcus luteus* (*M. luteus*). These

bacteria were sprayed onto a quartz plate measuring $30 \times 30 \times 0.4 \text{ cm}^3$ by a home-built nebulizer [2]. Eight UVC LEDs with a peak emission at 275 nm were mounted on either side of the quartz plate, with the objective of coupling their radiation into the quartz plate. (Fig. 3).

The typical initial concentrations employed in the experiments were approximately one million bacteria per square centimeter. This was considerably higher than the concentrations typically observed on touchscreens, yet it enabled the potential of this disinfection method to be demonstrated. Following each new contamination, the UVC LEDs were activated for a period of up to 150 seconds, with the remaining concentration of surviving bacteria on the quartz plate determined at ten to thirty-second intervals. Sampling was conducted using commercially available swabs with which defined areas of the touchscreen were sampled in a random order. The collected bacteria were then transferred to a buffer solution, and the resulting bacterial suspensions were distributed on agar plates at varying dilution levels.

The number of developed colonies was counted after one day in an incu-

bator at a temperature of 37 °C. The mean results of at least three series of measurements for each bacterium are presented in Fig. 4. The results demonstrated that the various bacteria exhibited different degrees of reduction. *M. luteus* was the least sensitive bacterium. Here, 150 s were required for a reduction of two log levels (99 %). For *E. coli*, however, 30 s were sufficient to kill even 99.9999 % (six log levels). In the case of the other bacteria tested, a reduction of three to four orders of magnitude was achieved within a 30-second period. Given that the typical germ concentration observed on touchscreens is of the order of a few hundred microorganisms per square centimeter, these reductions indicate that a touchscreen would be largely germ-free after irradiation.

Prototype device with one second disinfection procedure

In order to ascertain the efficacy of this method in a real-world setting, a quartz plate with an approximate area of $23.6 \times 16.9 \times 0.4 \text{ cm}^3$ (excluding any slight rounding) was mounted in front of a custom, particularly sensitive capacitive touchscreen of a cryotherapy device (Cryo7 from Zimmer Medizin-

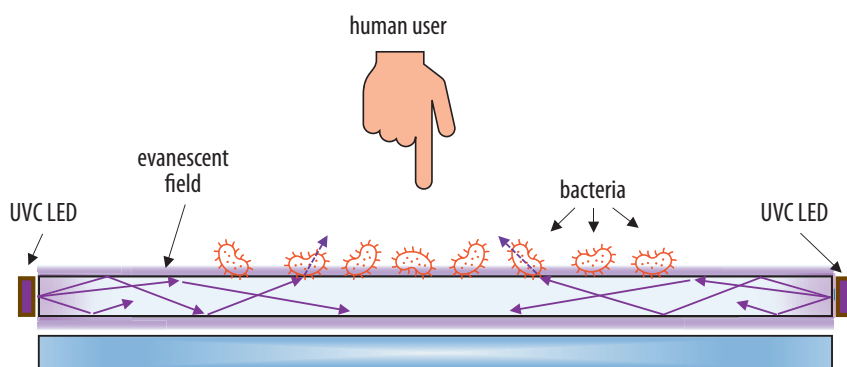


Fig. 2 Schematic cross section of the irradiation of microbial contamination on a quartz front plate by lateral UVC-LEDs. The principle of total internal reflection ensures that irradiation of the human operator is prevented (modified as per [2])

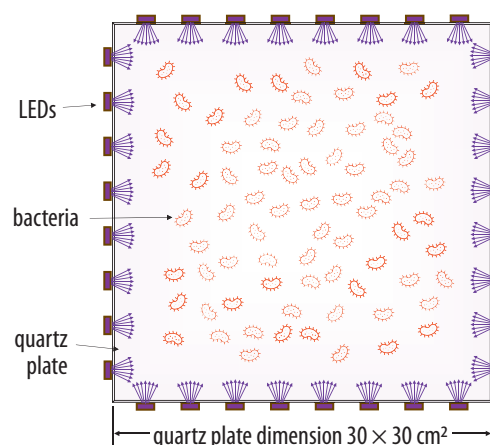


Fig. 3 Irradiation of a contaminated quartz plate by 32 lateral UVC LEDs (modified as per [2])

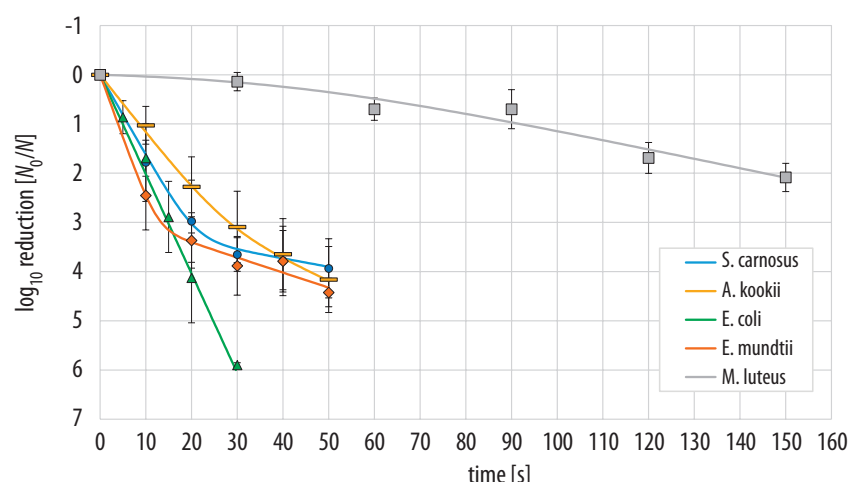


Fig. 4 Time course of the relative bacterial concentration during irradiation in a semi-logarithmic representation. For simplification, the concentrations of non-irradiated bacteria is not displayed here because there were hardly any changes during this short period (modified as per [2])



Fig. 5 Self-disinfecting touchscreen fitted to the Cryo7 cryotherapy device from Zimmer Medizinsysteme during disinfection. The visible violet impression is not caused by the UVC LEDs but by additional violet LEDs (modified as per [3])

systeme), which is shown in Fig. 5. Subsequently, the 275 nm radiation emitted by the 36 UVC LEDs, each with an output of 4 mW, was laterally coupled into the quartz plate from three sides. The functionality of the touchscreen was not impaired by the installation of the quartz plate and UVC LEDs.

The antibacterial efficacy of the radiation was evaluated through contamination with *Staphylococcus carnosus* on the quartz plate. The bacterial concentration was reduced by over three orders of magnitude after just a single second of UVC irradiation.

This prototype has so far only been tested on this bacterial strain. However, staphylococci are the microorganisms most frequently found on touchscreens, and the selected strain exhibits a similar UVC sensitivity to that of the pathogenic bacterium *Staphylococcus aureus*, which is one of the most important bacterial pathogens in hospitals.

User safety

Until now, the idealized assumption has been that no UVC radiation leaves the touchscreen in the direction of the human user. Unfortunately, this is not quite the case. In fact, an average irradiance of $35.2 \mu\text{W}/\text{cm}^2$ was measured at a distance of 1 mm from the contaminated quartz plate. According to various international standards and recommendations, the human skin or eye may only be irradiated with a maximum of $3 \text{ mJ}/\text{cm}^2$ per day at a wavelength of 275 nm [5, 6]. This limit would be reached after approximately 85 seconds. However, as the UV irradiation does not occur continuously, this would necessitate 85 disinfection procedures of one second each, during which a user would be required to maintain a distance of one millimeter in front of the touchscreen to reach this limit. Furthermore, the prototype device incorporates a number of safety features to prevent

operator exposure to UV radiation. These include the deactivation of the UVC LEDs when the touchscreen is in use or when a proximity sensor detects a person in front of the screen.

Additional safety by far-UVC LEDs

As illustrated in Fig. 6, all wavelengths within the UVC range have been demonstrated to exert a pronounced antimicrobial effect. However, in the so-called far-UVC range between 200 and 240 nm, the damaging effect on human skin and eyes decreases with decreasing wavelength due to the increased absorption of proteins at these wavelengths. This is why the daily permissible irradiation dose at 235 nm is $21.6 \text{ mJ}/\text{cm}^2$, and therefore approximately seven times higher than at 275 nm, according to the American Conference of Governmental Industrial Hygienists [6]. The application of

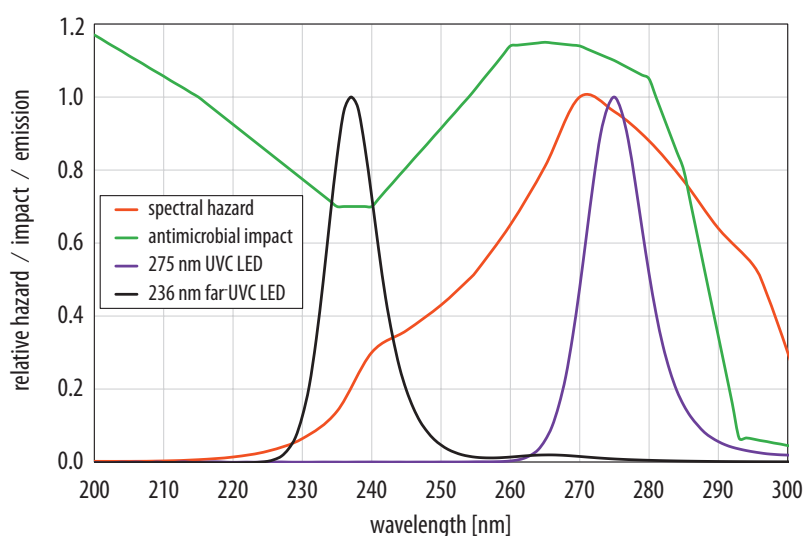


Fig. 6 Spectrally resolved relative antimicrobial impact and potential hazards to human eyes and skin for UV radiation in the range 200–300 nm according to DIN 5031-10 [8] and the ACGIH-TLVs [6]. The spectra of the UVC and Far-UVC LEDs employed so far are also illustrated [2, 3, 7]

shorter LED wavelengths would permit considerably higher daily exposure doses. Unfortunately, far-UVC LEDs are currently only available in low power and have shorter lifespans than longer wavelength UVC LEDs. However, they could be ideal for the future safe disinfection of touchscreens, particularly if their peak emission could be shifted to even shorter wavelengths. Their suitability has already been demonstrated [7].

Conclusion

The incorporation of an additional quartz plate and UVC LEDs could facilitate the rapid and automated disinfection of touchscreen surfaces in a manner that does not pose a risk to human operators. The prospective utilization of far-UVC LEDs could even serve to

reduce the risk to humans by an additional order of magnitude. This should serve to minimize the spread of pathogens or infections through touchscreens in public or healthcare environments.

*

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studied physics and medical physics, subsequently obtaining his doctorate from the Forschungszentrum Jülich. He then undertook a postdoctoral period at the Göttingen Laser Laboratory, after which he worked at Linos Photonics, later transferring to Hella. Since the end of 2005, he has held the position of professor at the University of Applied Sciences in Ulm.



Ben Sicks

obtained his bachelor degree in medical engineering from the Ulm University of Applied Sciences. His thesis on the reduction of bacterial contamination using visible light was duly awarded the Applied Optics Prize. Since completing his master's degree in medical devices, he has been engaged in research on diverse aspects of radiation disinfection as part of his doctoral thesis.



Kilian Noller

obtained his bachelor of engineering degree in medical engineering from the Ulm University of Applied Sciences in the summer of 2024. He was the winner of the 2024 Innovation Prize, awarded by the Wissenschaftliche Gesellschaft für Krankenhaustechnik, in recognition of his thesis on touchscreen disinfection. He is currently working as a developer at Zimmer Medizinsysteme.



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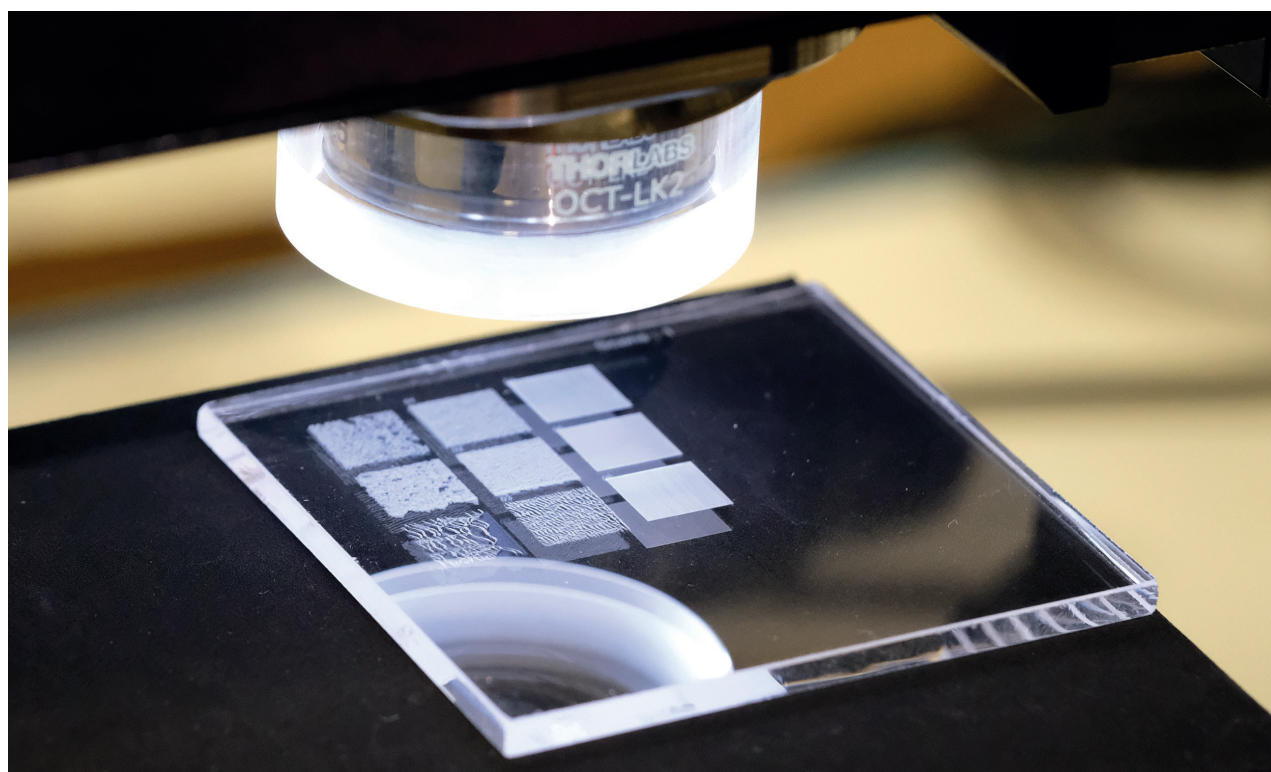
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How laser material processing can benefit from OCT technology

A qualitative and quantitative analysis of ultrashort-pulse processing of glass

Michael Seiler, Samson Frank, Dennis Thelemann, Oliver Elies, Pouria Teymori, and Jens Bliedtner



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Ultrashort-pulse (USP) laser ablation enables the creation of freeform shapes that are challenging to produce with conventional optics manufacturing techniques. To maintain the industrial standards of many branches, it is crucial to not only consider material removal rates but also the surface quality and subsurface damage (SSD). This study investigates the SSD patterns generated in fused silica and quantifies key parameters such as the SSD depth by applying optical coherence tomography (OCT).

Introduction to subsurface damage (SSD)

Microcracks, known as subsurface damage (SSD), can be induced during conventional mechanical manufacturing processes, especially for optical materials. A nearly SSD-free optical surface can be obtained for the final polishing steps using iterative processes in optics manufacturing. The remaining SSD reduces the overall performance of optics, such as the imaging quality, the laser induced damage thresh-

old (LIDT), and breaking strength. Due to the increasing demand for high-performance optics (e.g., EUV lithography), the urgency to develop a nondestructive measurement procedure to control SSD along the process chain has risen. Introducing laser-based techniques instead of conventional grinding in the optical industry can offer a promising alternative to shape optical surfaces. By focusing an ultrashort laser pulse down to tens of μm diameter, very high intensities are achievable that trig-

▲ **Fig. 1** USP laser-processed fused silica sample during measurement with a GAN621 spectral domain OCT system

ger nonlinear absorption and result in precise material removal on a micro and nano scale. The small tool dimensions and the reduced thermal damage are some of the many advantages of applying laser radiation in this process chain. In literature, defects occurring due to laser radiation are called laser-induced damage (LID). Further, SSD known

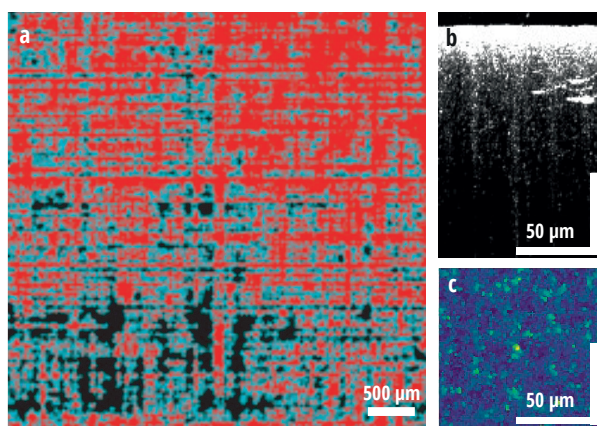


Fig. 2 Comparison of two SSD evaluation methods for laser ablation of optical materials: (a) microscopical image of destructive stepwise polishing of the surface, (b) sagittal visualization of non-destructive tomographic imaging with OCT, (c) color-coded SSD depth information (color scale: 0 – 156 µm) from OCT (top view)

from conventional manufacturing can also occur during laser material processing of optical materials and is also referred to as SSD in this paper [1–3].

Optical coherence tomography to measure SSD

In the industry, both destructive and nondestructive methods can be applied to characterize SSD [2]. The main drawbacks of destructive SSD evaluation methods, like taper polishing, are long processing times and their inability to measure inline at multiple and specific locations. There are several imaging methods for the nondestructive characterization of SSD, and each shows its own disadvantages. Currently no universal nondestructive measurement technique is available on the market that fits all the needs of the optics industry. To understand the difficulty of imaging SSD, it is important to know some key characteristics of microcracks. After pre-grinding, the cracks can reach a depth of 100 µm, which should be reduced to a few micrometers (<5 µm) before polishing. Understanding the formation of defect shapes, along with quantifying their depth and distribution, is critical to process development. Recent literature presents the potential application of optical coherence tomography (OCT) to detect surface defects, in

particular LID and SSD. OCT is based on white light interferometry and is well known from various medical and industrial applications for its tomographic imaging capabilities with high sensitivity, high speed and resolution of the order of a few microns. Those features make it a powerful tool for nondestructive testing, not only limited to SSD [4].

Measuring SSD in USP laser machining

One application from the current field of research is introduced in this section, highlighting the benefits of OCT for the laser ablation of optical materials. Schindler et al., cited in [5], introduced a destructive method to evaluate SSD after laser processing using stepwise polishing. His work investigated pico and femtosecond ablation strategies and three different wavelengths, applying fused silica and glass N-BK7 as a substrate. The results lead to a coloring of the SSD distribution for a specific polishing depth, as shown in Fig. 2a.

On the other hand, three-dimensional imaging with OCT can offer a nondestructive way to measure the depth and shape of SSD. It gives much more insight into crack formation during ultrashort-pulse laser ablation; see Fig. 2b and 2c. Frank et al. used the technology to reveal the effect of mate-

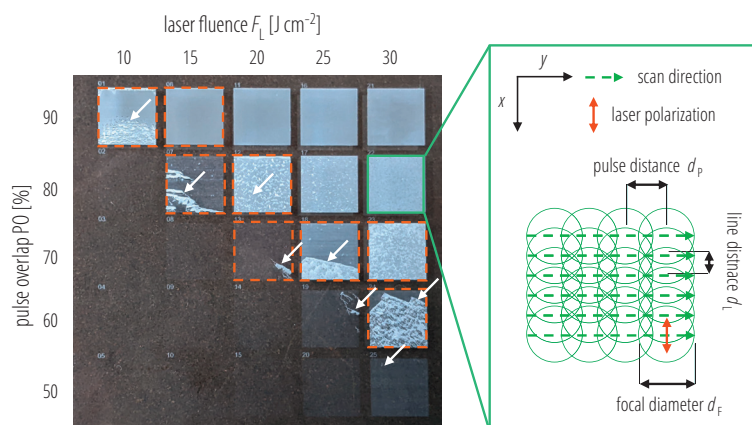


Fig. 3 Photograph of the 5 × 5 matrix on sample #1 after laser ablation. White arrows indicate areas of inhomogeneous processing results and only partial ablation on the substrate surface. Orange dashed boxes indicate alterations in ablation patterns during a reproducibility study

rial and process parameters on morphological features and detailed spatial distributions of SSD when processing glass N-BK7 and fused silica [5]. In this work, the method has been expanded to analyze the effect of scan direction and polarization on damage generation and patterns.

Experiments and methods

Flame polished fused silica glass (FN08) served as the sample material for this experiment. The 60 mm × 60 mm samples were cleaned in an ultrasonic bath before laser processing and measurement. Experiments were performed with an RDX1000FBS industrial laser machine from Pulsar Photonics. The machine houses an ultrashort-pulse laser (Trumpf TruMicro 5250) combined with an ExcelliSCAN scanning unit. The laser source provides a maximum average power of $P_L = 30$ W using a wavelength of $\lambda = 515$ nm. By means of an f-theta objective with a focal length of 100 mm, a focus diameter of 23 µm (measured with a Spiricon SP620U) can be achieved.

A TMS-1400 industrial white light interferometer from Polytech was used to measure the ablation depth. A GAN621 spectral domain OCT system from Thorlabs was used to perform OCT measurements. With each measurement, a 3D volume of up to

Sample #	Passes	Polarization	Scan direction for each field	Fluence [J cm^{-2}]	PO [%]
1	1	Linear ↕	Left to right →	20, 30	90, 80
2		Circular ↻	Left to right →	20, 30	90, 80
3		Linear ↕	Right to left ← Up to bottom ↓ Bottom to top ↑	20	90

Table 1 Processing parameters for laser ablation of fused silica

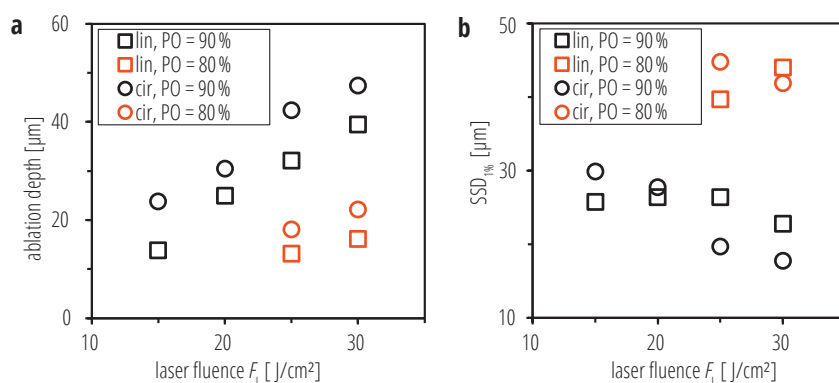


Fig. 4 (a) Ablation depth of linear (lin – sample #1) and circular polarization (cir – sample #2) depending on laser fluence F_L and pulse overlap PO for selected parameter sets with homogeneous ablation, (b) corresponding SSD depths for an area threshold of 1 %

$1.0 \times 1.0 \times 1.38 \text{ mm}^3$ was acquired. The raw data was further processed using various visualization techniques, e.g., 2D projections along the x-axis were generated to obtain cross-sectional images. The methods, including calculation of the SSD, are explained in detail in [5]. The SSD values presented in this report are calculated based on a 1 % area threshold, meaning that at the given depth, only 1 % of the total area contains deeper defects. Using SSD depths calculated from a suitable area threshold rather than the maximum SSD depths prevents single outlying defects from impairing the comparison between processing parameters.

Results

The experimental investigations are focused on the basic understanding of SSD formation. Therefore, the polarization of the laser beam as well as the pulse overlap and laser fluence were varied (see sample #1 and #2 in Table 1 and Fig. 1). The number of passes was set to one and the repetition rate kept constant at 100 kHz. The pulse spacing and line spacing were set to be equal. A field of $8 \times 8 \text{ mm}^2$ was processed for each parameter. The aim was to demonstrate the influence of the first ablation layer and its resulting damage to the substrate. To further investigate the influence of the scan direction on

the formation of SSD during laser processing, one additional experiment was carried out; see sample #3 in Table 1. This section presents the roughness and ablation depth results for the spatial distribution and shape of SSD using 3D OCT images and topographic evaluation of the processed area.

Fig. 3 shows a photograph of the 5×5 matrix on sample #1. The camera image visualizes different material interactions depending on the pulse overlap and laser fluence. As can be seen, only a pulse overlap of 90 % and laser fluence from 15 to $30 \text{ J}/\text{cm}^2$ exhibit homogenous laser ablation. In tests conducted to assess reproducibility, the fields highlighted with dashed boxes exhibited alterations in the ablation pattern. There are several fields with inhomogeneities as well as parameter combinations with nearly no interaction in the lower fluence regime, including smaller overlapping.

Fig. 4 displays the correlation between ablation and SSD depth as a function of laser fluence for linear and circular polarization after laser ablation. The diagrams include all parameter combinations that lead to homogenous ablation. Both a higher pulse overlap and circular polarization result in a larger ablation depth compared to linear polarization. This correlation changes when analyzing the SSD depth of the treated fields.

The highest amount of laser intensity is absorbed close to the surface by applying a 90 % pulse overlap, which leads to a homogenous treated area. Reducing the overlap results in a process threshold with an instable interaction between the laser radiation and the material surface. The radiation can cause damage under the surface and therefore higher SSD values. It can be seen that the SSD depth can be higher than the ablation depth for these parameter combinations. This understanding is crucial if the number of passes is insufficient to remove the damage caused by the first pass, starting from a polished surface.

Besides quantitative information, the OCT technology offers more insights into the formation of defects. The patterns generated in the transition zone between stable and non-stable processing (see orange fields and white arrows in Fig. 3) in particular can lead to sub-surface defects with a very high SSD depth. A more detailed view on such defects is shown in Fig. 5, investigating the influence of polarization and the scan direction. At the same laser fluence and pulse overlap, the scan direction was rotated by 90° while maintaining constant linear polarization. The formation of wave-like defects demonstrated a dependence on the scan direction, as observed for all altered directions. These defects were consistently orientated relative to the scan direction, as shown in Fig. 5e and 5f.

Summary

This work demonstrates the application of OCT technologies for the laser ablation of optically transparent materials. OCT is a powerful tool for 3D visualization as well as for analysis of the process. These insights deepen the understanding of defect formation and can accelerate process optimization. The observations can further help to find the causes of different morphologies. Future work can benefit from a stronger

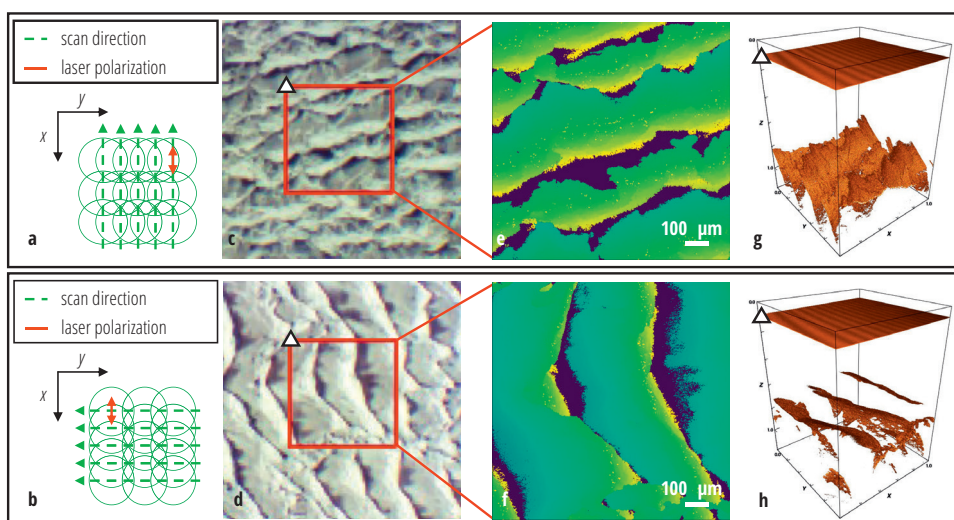
Institute

Ernst Abbe University of Applied Sciences

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

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Fig. 5 Influence of an aligned (a, c, e, g) and perpendicular (b, d, f, h) scan direction relative to laser polarization on defect patterns and orientation at laser fluence $F_L = 20 \text{ J/cm}^2$ and pulse overlap $PO = 90 \%$, (a, b) depiction of scan direction and laser polarizations, (c, d) microscope preview image of OCT measurement area, (e, f) color-coded depth maps with SSD in the range of $0 - 1,300 \mu\text{m}$, (g, h) 3D rendering of the acquired OCT data ($xyz: 1 \text{ mm} \times 1 \text{ mm} \times 1.38 \text{ mm}$)



correlation of other monitoring methods as well as simulative approaches.

*

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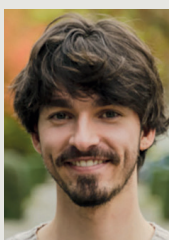
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Jens Bliedtner studied precision engineering at the Friedrich Schiller University in Jena. He wrote his doctoral theses in the fields of development of pulsed laser systems and special methods in macro material processing. Since 2000, Bliedtner has been a professor at the Ernst Abbe University of Applied Sciences in Jena and the head of the production engineering and automation of production processes department. Currently, he is working in the research fields of optical technology, laser material processing and 3D printing.



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Industrialization of additive manufacturing

End-to-end automation and virtualization as a key to successful business cases

Ingomar Kelbassa, Frank Beckmann, Dirk Herzog, Katharina Bartsch, Mirco Jankowiak, Julian Ulrich Weber, Philipp Kohlwes, Philipp Imgrund, Vishnuu Jothi Prakash, Matthias Brück



Source all images: Fraunhofer IPT

Our world is constantly facing a wide variety of social challenges – currently, issues such as climate change, security, demographic change, and resource conservation are of significant importance and show an acute need for action. Disruptive technologies, among other things, are needed to tackle such problems. Additive manufacturing (AM) is regarded as the ‘game changer / paradigm shift’ technology for the digital, automated production of the future – as the key enabler of ‘Production 2.0’.

This sustainable and resilient technology enables new paths to innovative solutions across all industries by providing a high degree of individualization (mass customization) and great design freedom (manufacture for design instead of design for manufacture). For example, internally cooled turbine blades for H_2 -capable gas turbines, lightweight structures for more efficient aircraft or patient-specific implants are only made possible by AM. AM then makes an important contribution to solving the social challenges mentioned above. Now it is necessary

to transfer this technology to broad industrial use.

Maturing AM processes

Industrialization of AM requires an end-to-end approach along the AM manufacturing route – from the initial design to the finished part, not limited to but including the AM process itself. Advances in process development, for instance, have led to process parameters for high-power lasers of up to 1.5 kW in the field of laser powder bed fusion.

Here, laser beam shaping opens up great potential for process efficiency

and stability. This is due to the fact that a Gaussian-shaped laser beam profile introduces too much energy into the melt pool in the center, whereas it is barely sufficient for melting at the edge. A ring-shaped beam profile, on the other hand, ensures an even distribution of temperature, which prevents evaporation effects and allows almost the entire laser energy to be used for material deposition within the process zone. Over the last ten years, the Fraunhofer IPT has studied the effect of different beam shaping technologies on a range of materials such as steel,

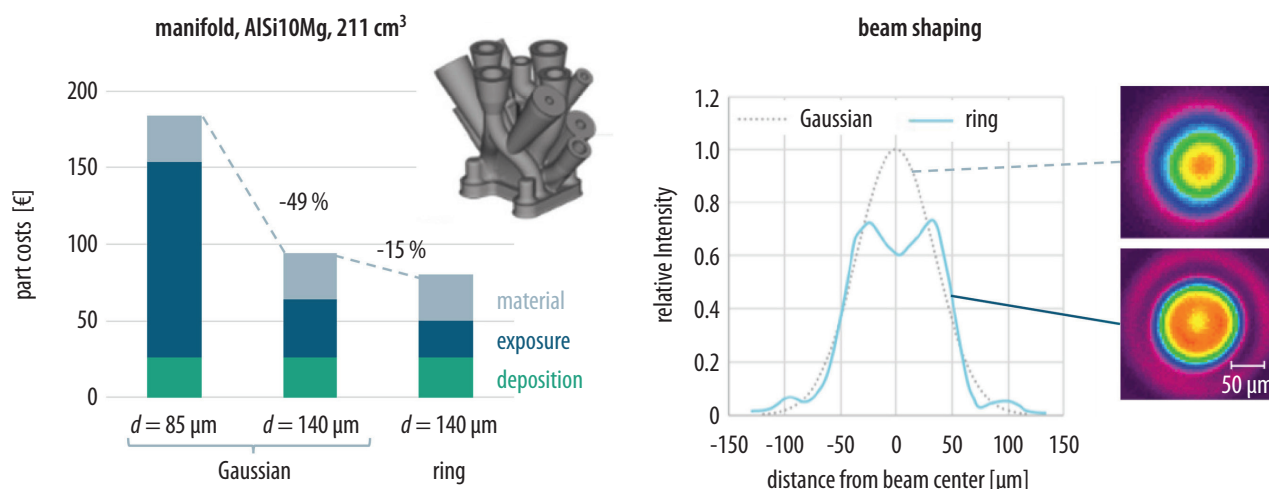


Fig. 1 Beam shaping in laser powder bed fusion and its impact on part costs demonstrated on a manifold

aluminum, titanium and copper, and an increase in the build-up rate was achieved with an increase in process stability in each case. This leads to a significant reduction in manufacturing costs, as there are fewer process interruptions and higher productivity at the same time. Depending on the material, build-up rates and process stability could be increased by a factor of two to three in fair comparisons, which can be translated into a significant reduction in part costs, cf. Fig. 1.

Newer technologies offer the option of dynamically adjusting the laser beam profile during the print job so that different laser beam shapes can be used for specific component areas. In addition to increasing the build-up rate and process stability, this technology can be used to specifically adapt the resulting properties in different areas of the components.

Merging virtual and physical worlds

To industrialize AM it is also necessary to merge the virtual and physical worlds through digital twins, enabling quality control and automated feedback into CAD/CAM processes. The Industry 4.0 initiative has led the way to widespread digitalization and virtualization

of manufacturing processes. In this context, a digital twin – a virtual replica of a system or process or a manufactured product – can significantly enhance the efficiency and quality of the process as well as the product. By systematically capturing and analyzing all relevant production data, digital twin models provide a comprehensive understanding of the entire manufacturing process.

Within the industry-funded 'Big-DataLMD' project, Fraunhofer IAPT has developed a data-pipeline infrastructure and associated software tools that enable the digitalization of an industrial powder-based laser metal deposition system. Equipped with Sinumerik Edge and in-situ optical sensors, the pipeline can capture machine parameters as well as process-related data. A product digital twin is then created in Siemens Insights Hub to capture and analyze data and to identify critical influencing factors. Fig. 2 shows the digital representation of an additively manufactured component based on data collected from in-situ sensors. The software tool also allows users to capture metadata from the downstream quality measurement steps. Recommendations for action are derived from the analyzed datasets to improve the stability of the powder-laser DED process.

A key advantage of the digital twin is the continuous and automated optimization of processes. Through data and AI-driven simulations, end-users can make precise predictions and identify potential sources of error at an early stage, thereby increasing the stability and accuracy of additively manufactured components.

End-to-end automation

Another big challenge in the industrialization of AM is posed by removal of the support structures of additively printed parts, which is currently done manually and is a significant barrier to industrial adoption. There is a big need for automation here because of the associated safety and health risks as well as the high costs and time expenditure. Automated solutions have been investigated and developed, such as removal using mechanical tools operated by industrial robots. Robotic chiseling, as shown in Fig. 3, was found to be a suitable process, cre-

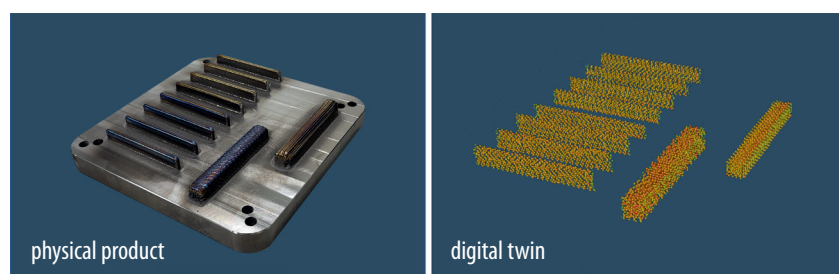


Fig. 2 Laser metal-deposited test geometry (left) and its associated product digital twin (right)

Institute

Fraunhofer IAPT

The Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT works to enable sustainable innovations in the field of additive manufacturing. The portfolio of activity includes research at a process and material level, enabling unique component designs, and providing system solutions for factory planning and virtualization. All aspects of the AM path are considered holistically from end-to-end, from the basic idea and feasibility up to industrial implementation in a production environment. Special attention is paid to the aspects of life science, energy, and mobility as well as security and defense.

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ating results equivalent to the current manual method.

With the help of a robot, the additively manufactured component is moved along a translationally oscillating chisel, which successively removes the supporting structures of this component mechanically. The arrangement of the individual supporting elements must be carefully defined to be able to remove support structures with this technology: the commonly used block supports have a high density and resistance compared to cone supports, for example. This can lead to complications with the support structures breaking, as a sufficient space between the individual elements is necessary to be able to cause initial plastic deformation. The support structures can also be equipped with predetermined breaking points or porous properties to optimize this process, and also to improve the final surface of the machined part. A camera can be integrated into the process to further increase the degree of automation: this allows progress of the process to be tracked as well as the optical support structure to be recognized. Direct communication with the robot enables specific regions of the component to be revisited and any support structures remaining after the first pass to be removed. With the feasibility proven, the optimization of support structures and the integration of suitable automation solutions can make an important contribution to end-to-end automation.

Additive manufacturing can be successfully industrialized by the holistic and consistent transfer of individual progress along the manufacturing path.

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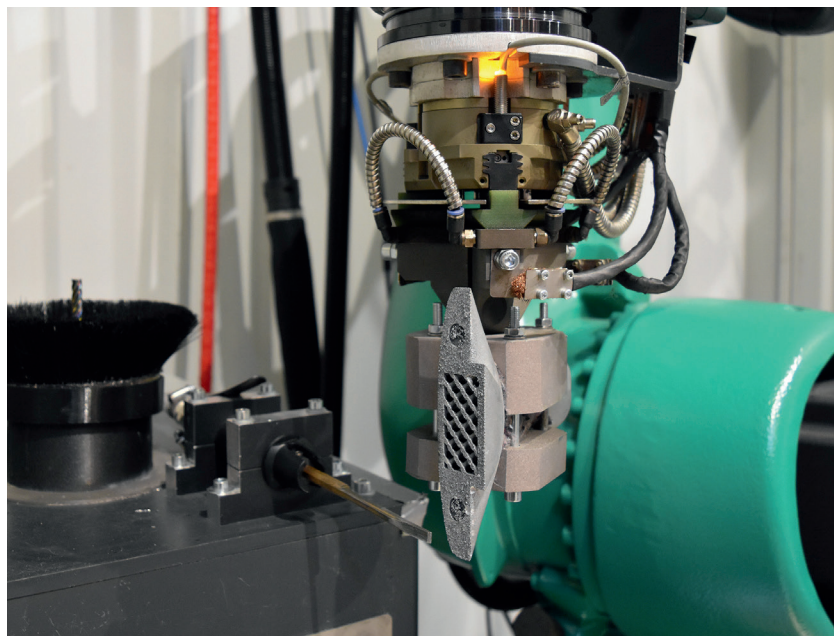


Fig. 3 Robot-assisted automated removal of support structures shown on a part with sections of solid material and lattices

Authors

Ingomar

Kelbassa has a clear goal as director of the Fraunhofer IAPT: to ensure that 3D printing is used on a large industrial scale. He earned his doctorate at the Fraunhofer ILT in Aachen in 2006 and remained as deputy director and deputy head of the chair of the LLT at RWTH Aachen University until 2016. As from then, he led the manufacturing technology



Source: private

development of the 'gas and power' division and was also in charge of the division 'company core technology, additive manufacturing' at Siemens AG. Most recently, he was managing director of the Siemens subsidiary Weiss Spindeltechnologie.

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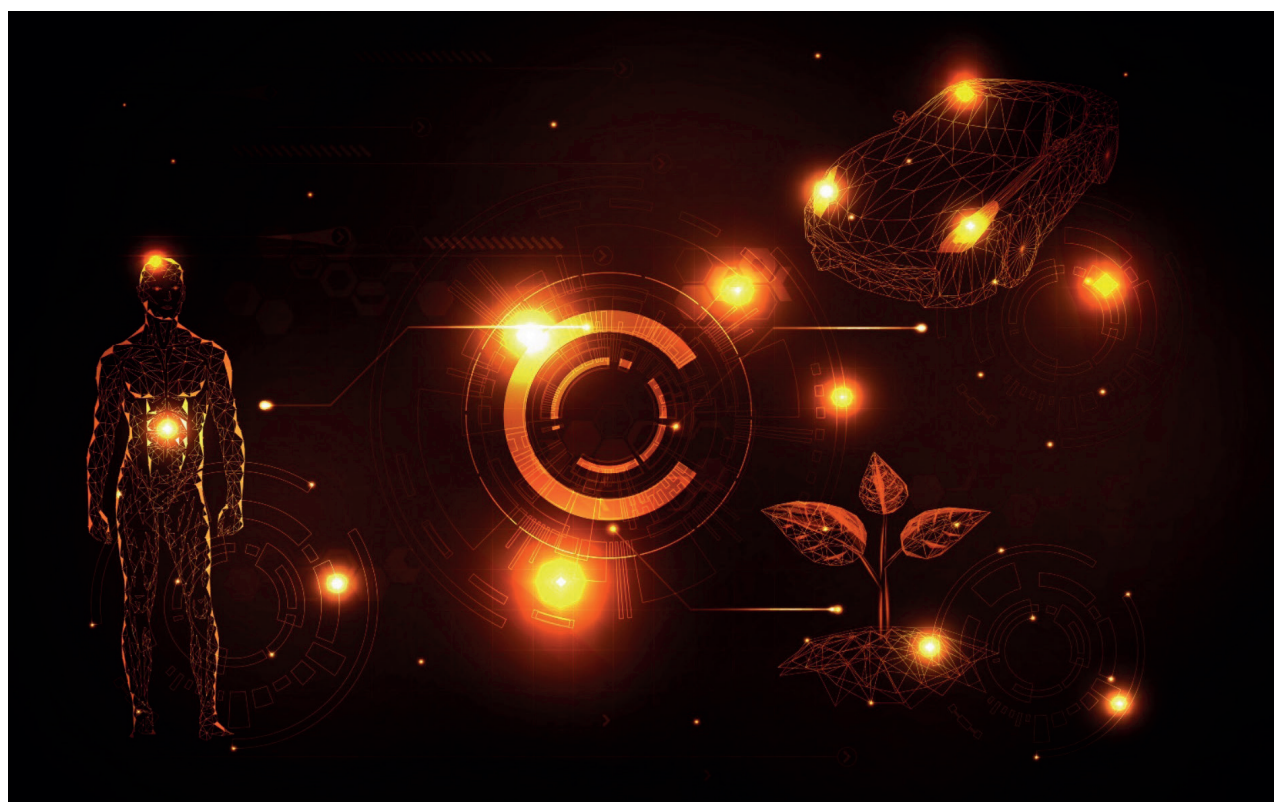
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Smart photonic sensors

Systems for transforming the automotive, agriculture, and healthcare sectors

Ivan Nikitskiy



Source: Retina

A new EU initiative of 6.1 million euros, Retina is a four-year project aiming to combine advanced spectral imagers and photonic chip-based lidar sensors into versatile multimodal perception systems to revolutionize the healthcare, automotive, and agriculture sectors. This article explores Retina's key objectives, technological developments, and applications while also addressing ongoing challenges and potential directions for future development.

Coordinated by **AIMEN**, a research institute in Pontevedra in northwest Spain, the Retina project comprises a 13-member consortium of leading European researchers and technology companies. Retina's primary goal is to address a significant limitation in current sensor systems, namely that current sensor systems rely on either spectral imaging or lidar, which leads to incomplete data or a lack of versatility in varied environments. Accordingly, Retina seeks to develop spectral imaging and lidar technologies and combine them together into a single system capable of providing a comprehensive analysis of both spatial (3D)

and spectral (material composition) data in real time.

Retina aims to harness the power of photonic integrated circuits (PICs), quantum dots (QDs), and advanced CMOS and InGaAs detectors across the visible-to-near-infrared (VNIR) and short-wave infrared (SWIR) ranges. The aim is to couple these technologies with a digital infrastructure for machine learning algorithms to enable the development of multimodal sensing applications that offer unparalleled light sensitivity and spectral range. Novel PIC-based lidar uses tilted grating coupler arrays for non-mechanical beam steering and FMCW modulation, fab-

ricated on an InP substrate to provide the advantages of full integration in the chip, immunity to other lidar signals, and low power consumption.

Meanwhile, snapshot spectral imagers are based on QD-based SWIR sensors and pixel-level optical filters to provide a compact design, video capability, and compatibility with conventional image processing pipelines. The machine learning (ML) platform incorporates specific data elaboration techniques and data fusion with edge deployment of the ML models, thereby providing the advantages of being specific to hyperspectral images and point clouds, with a complete pipeline of

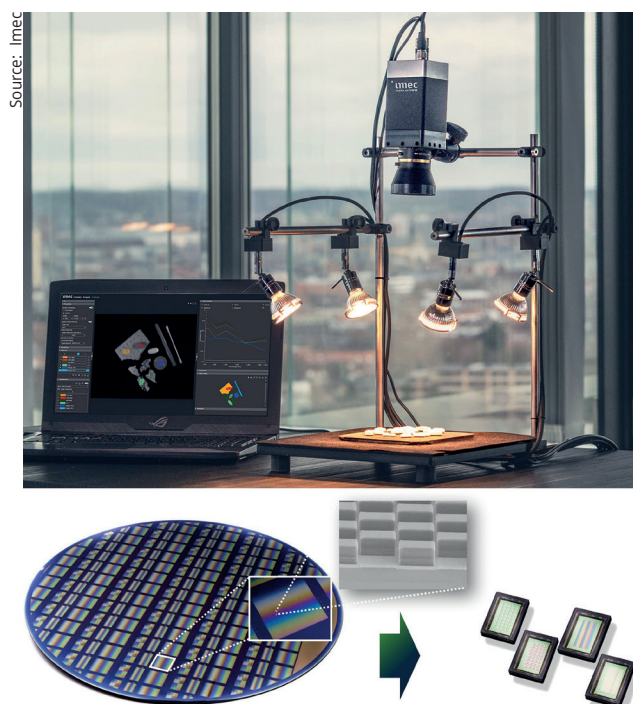


Fig 1 (top) Imec's SWIR image sensor under test, (bottom) narrow-band optical filter structures are processed at the wafer level on top of a commercial image sensor wafer and packaged imaging sensors with various filter designs. On-chip spectral filter integration enables customized SWIR imaging solutions

data processing all in the same place. In addition to coordination, AIMEN's role includes low-level signal processing and validation of ML algorithms.

Validation of the technology is for three use cases: medical – detection of tumor cells and critical structure and assessment of perfusion and oxygenation; automotive – sensing for obstacles and collision detection under complex weather conditions; agriculture – sensing solutions for early detection of grapevine trunk diseases (GTD), water

stress monitoring, and real-time estimation of harvest quantity for productivity forecasting.

Medical use case

Retina's medical use case focuses on the detection of tumor cells and critical structure, and the assessment of perfusion and oxygenation, using short-range lidar, SWIR and VNIR spectral imagers, and commercial RGB cameras. A key participant is Quest Medical Imaging, a Dutch company and part of the Olympus group, who develop and manufacture medical fluorescence imaging systems. Their intra-operative medical imaging system uses NIR laser light to obtain fluorescence images, which, together with standard color images, make identification and navigation easier for the surgeon. Laser light is directed onto the tissue, which excites the fluorescent dyes to enable, for example, the detection of tumors or to identify the sentinel lymph node (not FDA approved), which will be assessed to see whether any metastases are present. Similarly, in assessing tissue perfusion (the flow of blood or fluid to tissues and organs), the intensity of the fluorophore traveling through the body can be measured. As shown above, the inflow and outflow of the fluorescence marks a change over time, indicating how well the tissue is

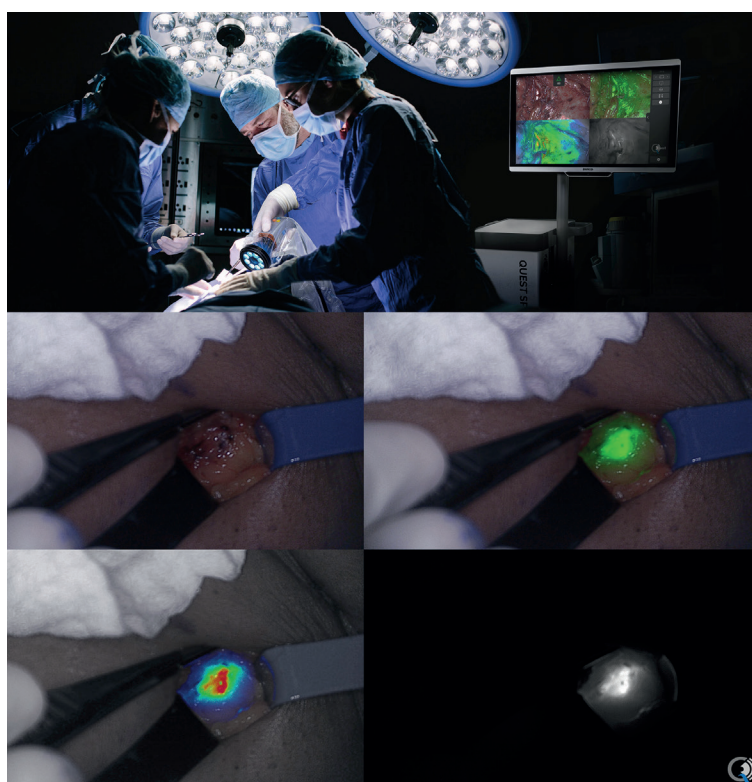


Fig 2 Intra-operative fluorescence imaging and sentinel lymph node detection (not FDA approved)

perfused and any vascular problems, for example in breast reconstruction.

In collaboration with Leiden University Medical Center, the Netherlands-based **Quest Medical Imaging's** role in Retina's medical use case is to investigate user needs, and to integrate the knowledge obtained from using their own medical devices in the field. They will also provide test data and phantom material for the initial testing and further development of the algorithms. In addition, they will put together a demonstrator comprising integrated lidar and multispectral sensors to investigate clinical user needs in relation to reduced background signal and optimized penetration depth and to see whether a 3D structure can provide additional information for annotation and processing compared to a 2D image.

The company providing the multi-spectral sensors for the demonstrator is **Imec**, an international research and development organization headquartered in Belgium. Imec's approach is to develop on-chip spectral filters that are deposited directly onto an image sensor to create miniaturized, compact, and robust systems. And because the technology is mass-producible, it is scalable with lower production costs and easier integration. Furthermore, multiple wavelengths can be acquired by using

Organization

EPIC – European Photonics Industry Consortium

EPIC is the world-leading photonics industry association representing more than 800 members across 35 countries. EPIC promotes the sustainable development of organizations working in the field of photonics. EPIC fosters a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement. EPIC publishes market and technology reports, organizes technical workshops and B2B roundtables, supports EU funding proposals, advocacy and lobbying, education and training activities, standards and roadmaps, and pavilions at exhibitions.

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different kinds of filters, enabling snapshot and video acquisition. Another advantage of this approach is that it offers customizable patterning solutions, including hyperspectral, multispectral, linescan, and snapshot mosaic sensors in the VIS (460 – 600 nm) and VNIR (600 – 850 nm / 670 – 950 nm) ranges. Their multispectral snapshot SWIR sensors, based on InGaAs, are also capable of video acquisition, and therefore very often useful for applications that are more dynamic. However, they are also working on a new type of sensor based on quantum dots consisting of stacks of thin films with a thickness lower than the targeted wavelengths. The advantage of these sensors over InGaAs sensors is that they have a higher pixel density and a higher spatial resolution with lower production costs. For Retina's medical use case, Imec is integrating their snapshot SWIR sensor with a lidar system in a multisensor system comprising various image sensors, i.e., HD RGB, spectral VNIR, SWIR, and lidar by means of a beam splitter.

Fraunhofer Heinrich Hertz Institute (HHI) is also playing an important role in the development of Retina technology by using their knowledge of miniaturization and photonics integration on an MPW (multiproject wafer) platform to help make Retina technologies compact, energy-efficient, and suitable for integration into versatile, scalable systems. They also have expertise in developing novel chip-based lidar systems.

Automotive use case

Retina's automotive use case involves multimodal sensing for obstacles and collision detection in all weather conditions, using long-range lidar and commercial cameras. One of the developers of the lidar system is **QOPHI Lab** (Quantum, Communication, Photonic, and Integration Lab), which is located at the University of Vigo in northern Spain.

QOPHI's contribution is in two areas: the addition of grating couplers and microlenses to the Fraunhofer Institute's existing MPW platform and the development of frequency-modulated continuous wave (FMCW) lidar PICs to meet the lidar requirements in terms of laser power, linewidth, FOV, etc.

Traditional lidar systems are based on the time-of-flight (TOF) principle, which measures the time it takes for

a pulse of light to travel to an object and back to the sensor, with distance calculations based on the speed of light and the measured time delay. In contrast, instead of pulses, FMCW lidar systems continuously emit laser light with a varying frequency (modulated wave) and measure the difference in frequency between the outgoing and returning signal (Doppler shift), which provides both distance and velocity information.

FMCW lidar systems have several advantages over TOF lidar, such as less power consumption, immunity to interference from other light sources, the ability to simultaneously measure distance and velocity, and the ability to be fully integrated onto a single chip.

Another contributor to the automotive use case is **Xenomatrix** from Belgium a pioneer of solid-state lidar with over a decade of experience in lidar development. Xenomatrix' role is to represent the end user by defining system requirements for function and integration. Through interactions with leading Tier-1s and OEMs in the automotive world, Xenomatrix has gathered a list of minimum and maximum fundamental requirements in relation to resolution, range, field of view, accuracy, frame rate, and power consumption, and from these data they have come up with the ideal lidar. They will also help to develop AI algorithms to process visual camera and lidar data for road users and object detection to improve collision avoidance in all weather conditions. While waiting for the lidar sensor's development for this project, Xenomatrix will provide example data from their lidar system to initiate the AI development. They will also be involved in testing the fundamental performance of the lidar systems developed under the project.

Agriculture use case

Retina's agriculture use case focuses on viticulture and the early detection of grapevine trunk diseases (GTD), water stress monitoring, and real-time estimation of harvest quantity for productivity forecasting. Monitoring can be done both ground-based using short-range lidar and SWIR and VNIR spectral imagers and drone-based using long-range lidar and SWIR and VNIR spectral imagers.

Pioneers in the manufacture of high-performance CMOS imaging systems since 2001, the Swiss company

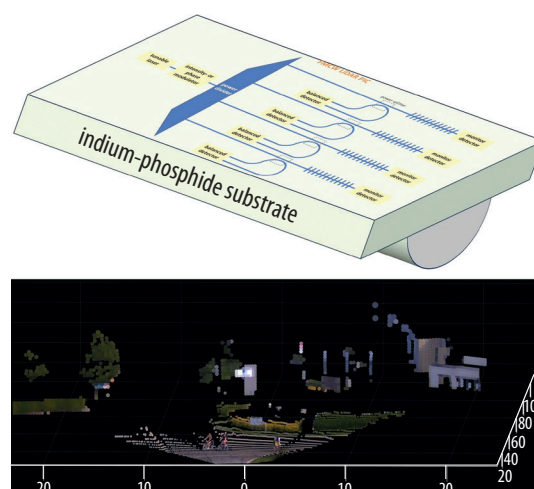


Fig. 3 Schematic of the lidar chip proposed in the Retina project and colored 3D dataset obtained from a commercial lidar used to initiate AI system developments by Retina. Axes show distances in meters (Source: Fh HHI / Xenomatrix)

PhotonFocus has developed an embedded AI platform for drone-based hyperspectral imaging (HSI). From extensive experience with drone imaging systems, they develop their products to achieve high performance with low power consumption. To this end, the drone system uses HSI cameras from their MV4 platform, which incorporate cost-optimized VNIR sensors and SWIR snapshot imagers from Imec, a high-performance, low-power image processing platform, a low-power 10GigE interface, and improved cooling structures. Validating the technology and representing the wine producers is Colab Vines & Wines, an initiative of the Portuguese wine sector led



Fig. 4 A vineyard in Portugal and a SWIR image of wine leaves generated by a commercial SWIR camera

by the Association for the Development of Duriense Viticulture **ADVID**, headquartered in Vila Real in the Douro wine region in northern Portugal.

Grapevine trunk diseases are a range of fungal species that are a major threat to viticulture because they cause plant death and a decrease in vineyard productivity. A fundamental problem is that primary symptoms develop on the trunk, while secondary symptoms can develop on the leaves up to five years after contamination, making early diagnosis difficult. As fungicides such as sodium arsenide have been banned in Europe, there is now an urgent need for effective early identification measures so that vines can be removed as soon as they are infected, preventing contamination of the neighboring plants.

ADVID's solution is to use ground-based short-range lidar and SWIR as well as VNIR spectral imagers for early identification of GTD, and drone-based long-range lidar with SWIR and VNIR spectral imagers for the canopy.

Another threat is drought, and the pressing need for effective water stress management to help producers better control the impacts of climate change on grape quality. Currently, measurements of predawn leaf water potential are taken during the night by cutting a single leaf and its stem from the vine and placing them in a Scholander pressure chamber. Although this is a reliable method, measurements are made by sampling, thus reducing the spatial distribution (knowledge of how water stress varies across different sections of the vineyard), and as the procedure is labor-intensive and time-consuming, it is also expensive.

As a solution, ADVID use ground-based, short-range lidar with SWIR and VNIR spectral imagers, which establishes the spatial distribution of water, enabling timely intervention and improved grape yield and quality.

In the same way, drone-based long-range lidar in tandem with SWIR and VNIR spectral imagers will enable 3D mapping of vineyard landscapes by capturing accurate measurements of the canopy density, height, volume, and row spacing.

The drones will be deployed by **Aeromedia**, a Spanish leader in drone-based imaging solutions with expertise in aerial data collection. They will ensure the seamless operation of the sensors to optimize data acquisition

and transmission protocols from the air to the ground-based systems.

Integration and commercialization

For all use cases, advanced image analysis and optimization are crucial to enabling efficient data handling and improving real-time imaging accuracy. For this reason, a key partner in the consortium is **Abraia**, a Spanish company specializing in media processing using machine learning. Through its industry expertise and extensive network within the photonics sector, the European Photonics Industry Consortium (**EPIC**) is ensuring the project's visibility and communication to external partners and potential future adapters through their technology meetings, exhibitions, webinars, and publications.

On the commercial side, the French consultancy **Tematys**, which has extensive experience in market analysis and business development for photonics and optical technologies, is conducting market studies and analyzing the commercial potential of Retina technologies across a range of industries. They also provide go-to-market strategies, regulatory guidance, and support for intellectual property management.

Challenges and future prospects

While the Retina project represents a major advancement in sensor technology, its implementation is not without challenges. To integrate the two complex technologies – spectral imaging and lidar – it will be necessary to overcome technical obstacles in data fusion, processing speed, and sensor calibration. Addressing these issues is essential because the systems need to be both accurate and affordable for widespread adoption, particularly in cost-sensitive

sectors such as automotive and consumer electronics.

Nevertheless, looking forward, the Retina project has the potential to set a new standard in machine perception. As more industries adopt this technology, it will inspire further innovation in sensor integration, leading to even more compact, efficient, and versatile systems.

Although challenges remain, the Retina project is an excellent example of how coordinated collaboration among research institutions, technology companies, and end users can drive innovation and advancements in photonics technology that benefit various sectors of society. Retina's multimodal perception systems mark a transformative development in machine sensing and perception. By combining spectral imaging and lidar into a single, efficient platform, Retina will provide a more complete environmental understanding for machines, facilitating improvements in safety, efficiency, and decision-making in various fields.

So far, the focus has been on enhancing the precision of autonomous vehicles, supporting medical diagnostics, and improving agricultural production – but the applications of this technology are enormous, with the potential to impact areas not yet imagined.

*

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Source: MackBrooks



Source: Mesago / M. Kutt

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May 06 – 09, 2025

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

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<https://w3-fair.com>

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<https://world-of-photonics.com>



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

"A triumph of innovation and resilience"

Review: EuroBLECH, 22 – 25 October 2024, Hanover, Germany

Amidst ongoing global challenges, the sheet metal working industry showcased its dedication to progress and growth at the 27th International Sheet Metal Working Technology Exhibition. With 38,946 trade visitors from 114 countries and 1,317 exhibitors on 160,000 sqm gross space, Euroblech reaffirmed its role as the world's leading platform for innovation and business in this sector. A sense of cautious optimism dominated the halls, with many exhibitors securing substantial orders.

Despite the slowing global economy, there was widespread agreement that key markets will eventually bounce back and grow, together with a clear commitment to driving the necessary transformational change. Determined to focus on new opportunities, the industry has been intensifying its push for innovation. The proactive stance on technological progress was matched with a notable willingness from buyers to consider new investment.

The four-day event delivered massively on visitor quality, with the major-

ity of visitors classifying as key decision makers. The number of unique visitors increased by 3 %, with a strong presence from Germany which has recently gained in market importance for certain technology sectors. Besides Germany, the top visitor countries were the Netherlands, Italy, Poland, Sweden, Turkey, Austria, Spain, Belgium, Denmark, and Switzerland. There has been a significant growth in visitor numbers from Asia (Japan, Taiwan, India) and South America (notably Argentina), pointing towards promising new markets for the sheet metal working industry.

Nine exhibition halls hosted a wealth of product launches and groundbreaking innovations, sending a bold signal for technological progress and growth opportunities within the sector. Throughout all fifteen technology areas, machine makers displayed a clear commitment to enhancing production efficiency through technical innovation.

Key technologies included a new AI vision system for fully automated sorting of laser-cut parts, remote machine



Source: MackBrooks

EuroBLECH 2024, Hanover, Germany, 22 – 25 October

diagnostics and monitoring for fast troubleshooting and servicing, highly automated factory systems that integrate people, machines, and data into smart production flows, simplified and robust laser-cutting machines particularly suited for new users, a substantial 20 kW high-speed and high-precision fiber laser cutting machine for extra demanding applications, and many other advancements.

Euroblech 2026 is set to take place from 20 – 23 October 2026, again in Hanover, Germany.

<https://www.euroblech.com>

The 14th conference has become more international

Review: 14th Jena Laser Conference, 6 – 7 November 2024, Jena, Germany

A key event for the photonics and laser industry, the Jena Laser Conference welcomed over 180 participants for two exciting days in early November. The conference highlighted cutting-edge research, industry innovations, and international collaboration. A highlight of the event was the strengthened collaboration with Lithuania, a global leader in photonics and laser innovation.

Lithuanian experts shared insights into ultrafast lasers, advanced beam shaping, and high-power laser technology, showcasing the importance of global cooperation in driving innovation.

The conference featured outstanding keynote talks. Among others, Dr Jochen Stollenwerk (Fraunhofer ILT) discussed laser fusion as a sustainable energy solution, Dr Michael Kösters (Trumpf Laser) presented on high-power lasers for EUV lithography, and Prof Ingomar Kelbassa (Fraunhofer IAPT, cf. p. 56) highlighted the

transformative impact of digitized additive manufacturing. Alongside the keynotes, the agenda included sessions on laser material processing, optical coatings, and dynamic beam shaping, offering attendees a chance to explore the latest advances and connect with leading experts.

A standout feature was the industry exhibition with 23 renowned exhibitors, including Jenoptik, Light Conversion, Active Fiber Systems and many more. The exhibition provided an excellent platform to see the latest technologies and foster collaboration between academia and industry.

Jointly organized by OptoNet, IFW Jena, Friedrich Schiller University Jena / IAPT, and the University of Applied Sciences Jena, the Jena Laser Conference continues to be a leading forum for advancing laser technology. The organizers thank all speakers, participants, sponsors, and exhibitors for making this event a great success and



Source: OptoNet

Economic attaché Inga Rovbutas (Lithuania), Anke Siegmeier (OptoNet), Kristina Ananičienė (LITEK), Ambassador Giedrius Puodžiūnas (Lithuania), Nora Kirsten (OptoNet)

look forward to the next edition in 2026.

PhotonicsViews issue 5/2024 featured several conference contributions in a special section, e.g. articles from Active Fiber Systems, Asphericon, Ekspla, Lasea, LCP Laser-Cut-Processing, Robust AO, or TU Chemnitz.

<https://lasertagung-jena.de>

Industry meeting in difficult times

Review: SPS, 12 – 14 November 2024, Nuremberg, Germany



An impression of SPS 2024

The automation industry is navigating through difficult waters. High inventory levels and a lack of incoming orders continue to depress sales following previous supply chain shortages. The concept of China as an extended workbench, which has significantly boosted the European and German economies over the past twenty years, seems to be coming to an end. And after recent political developments in America and

Europe, the signs increasingly point to protectionism rather than free trade and open borders. The mood at many companies was therefore cautious but also optimistic.

In such times, a get-together of the industry is all the more important. With 51,291 visitors, the organizer Mesago was even able to record a slight increase of around 1,200 visitors compared to the previous year.

On the company side, however, there was a decline from 1,229 exhibitors in 2023 to 1,114 exhibitors this year – a decrease of 9.3 % – while the exhibition area remained almost the same at 125,000 m² compared to 128,000 m² the previous year. Nevertheless, the figures also reflect the partly tense economic situation of many companies.

It was also evident this year that European and especially German market participants in the field of digital automation are still playing in the

top league technologically. Under the motto “Bringing Automation to Life,” the focus was among other things on the application of artificial intelligence in the field of automation and in the context of ongoing digital transformation. In particular, the potential to further increase efficiency and the advantages in productivity were highlighted. Accordingly, the trade fair forums also provided insights into topics such as AI in automation and digital transformation.

The skills shortage has also reached the automation sector. This year’s SPS tried to address this with a makeathon and the Young Talents Day. Two job fairs also provided an overview of current job offers.

The next SPS will take place 25 – 27 November 2025 in Nuremberg, thus returning to its original date after the end of the pandemic.

<https://sps.mesago.com>

Showcasing new approaches to more sustainable, effective, and flexible production

Review: Formnext, 19 – 22 November 2024, Frankfurt, Germany



An impression of the first day of Formnext

Formnext once again made Frankfurt the global center of additive manufacturing (AM) and the latest production technologies. The expansion of the range of applications for industrial 3D printing and the emergence of faster, more cost-effective AM production was also very evident. This was seen not only in the presentations by the exhibitors and this year’s partner country Australia, but also in the extensive supporting program of lectures and events.

Despite a challenging economic environment and global uncertainties, Formnext 2024 has again confirmed its leading position. With 864 exhibitors (of whom 61 % were international), Formnext set new standards once again. The event showed clearly how additive manufacturing is increasingly gaining in importance in a wide range of industries. The 34,404 experts and executives (of whom 48 % were international) that Formnext welcomed as visitors this year are proof of this.

The broad applicability of additive manufacturing across numerous industries was strikingly demonstrated by the multifaceted supporting program and the various showcases. Visitors were able to discover pioneering solutions to help them optimize and future-proof their production processes.

With a multitude of world premieres and exciting innovations along the entire process chain, Formnext exhibitors helped to pave the way for an even wider range of applications for

AM in the future. For manufacturers of AM systems, productivity was at the top of their innovation agenda, which was reflected in new solutions in the field of automation or specialized systems for particular applications. At the same time, the sustainability megatrend continued to play a prominent role – from the exhibition stands, which were printed from sustainable materials, to facilities for material recycling.

Formnext 2024 has significantly expanded its already extensive supporting program once again. Numerous showcases focused on user industries ranging from the dental and medical sectors to the packaging and construction industries and mechanical engineering. Key trends, technologies, and applications were discussed in the extended multistage program with three presentation stages that were freely accessible to visitors.

Next year’s installation is scheduled to take place from 18 – 21 November.

<https://formnext.mesago.com>

Preview: TOP Conference

Telecommunications, Optics & Photonics Conference, 25 – 26 February 2025, London, UK



TOP returns 25 – 26 February 2025 for its fourth year to a new location, The Kia Oval – Surrey County Cricket Club, London. The conference will provide excellent networking opportunities for optical and photonic component and systems manufacturers and developers, along with fiber infrastructure and data center providers. It will focus on the development and application of optics and photonics in telecommunications and data

centers, along with presentations on photonic components and free-space optics.

If you have cutting-edge research or innovative technology to share, now is the time to submit your speaking proposal! TOP Conference welcomes contributions from industry experts, technologists, and academics to present in-person in February.

Whether your work focuses on telecommunications, data centers, photonic

components, free space optics, photonics for RAN, or quantum communications, this is your chance to take to the stage.

Featuring a limited exhibition space, TOP Conference gives you the chance to meet and network with many of the leading technical experts in the optical and photonics industries and includes a conference pass to join the sessions throughout the two days.

<https://topconference.com>

Preview: W3+ Fair

Innovation engine Wetzlar, 19 – 20 March 2025, Wetzlar, Germany



It is a promising contact platform – the W3+ Fair Wetzlar, the high-tech trade fair and conference, once again promises two days full of inspiration and exchange. Experts in key technologies from the region and far beyond will gather in the economically strong high-tech region of Wetzlar / Mittelhessen to explore new business opportunities and jointly launch technological innovations. The focus is on key fields of application such as semiconductors, medical technology, life sciences, mechanical

and plant engineering, AI and robotics, automotive, and aerospace. Prominent representatives from the region include companies such as Carl Zeiss SMT, Hensoldt Optronics, OptoTech Optikmaschinen, Harmonic Drive, Helmut Hund, and SPEA. Numerous exhibitors such as Märzhäuser, LK Mechanik, Hoyer Montagetechnik, Bandelin electronic, Fibotec Fiberoptics, AuTeBa, and Mountain Photonics are exhibiting at the trade fair for the first time.

Knowledge transfer is a top priority at the W3+ Fair. The accompanying conference “en-tech.talks”, which is supported by many partners – above all the gold partners Wetzlar Network and EPIC – will start with the thematic block “Semiconductor technology from Central Hessen”. Other main topics include laser development, transformation in the automotive industry, an EPIC TechWatch, industrial image processing with AI, and modern optics.

<https://w3-fair.com/wetzlar>

Preview: Laser World of Photonics

The entire photonics spectrum, 24 – 27 June 2025, Munich, Germany



The latest trends and innovations in photonics will once again be the focus of the next Laser World of Photonics, beginning June 24 at the Munich Exhibition Center. The accompanying congress will already start on June 22. The two events being held in parallel, World of Quantum and Automatica, will also provide exciting added value and a view outside the box.

The next Laser World of Photonics features a new logo and design that represents the colorful diversity of light. “More than half a year before the trade fair, all the key players in the industry have already confirmed their participation. Exhibitors currently cover almost 40 countries and regions, and there are 14 international joint stands,” says exhibition director Anke Odouli. In five

halls with eleven exhibition areas, the trade fair covers the entire spectrum of photonic technologies. The Integrated Photonics Area in Hall A2 has been given more space for the addition of a forum area to reflect the growing importance of this branch of photonics.

The MedTecLIVE Healthtech Pavilion, a special joint area of Laser and Automatica (Hall A4), will celebrate its premiere in 2025. For the first time, it will bring developers from medical technology manufacturers together with experts in laser technology, automation and robotics. The joint stand is being organized by Messe München in cooperation with MedtecLIVE, Europe’s leading trade fair for medical technology, as well as VDMA Health Tech and Bayern Innovativ.

Two Nobel Prize winners, Anne L’Huillier and Ferenc Krausz, will be at the World of Photonics Congress 2025. The field’s international scientific elite meets every two years at Europe’s largest photonics congress to discuss all aspects – from the lab to industrial applications. It will combine five conferences under one roof: the largest is CLEO/Europe-EQEC, which addresses all facets of optical technology and photonics in basic research. In addition, there will be four conferences on applied science, namely LiM – Lasers in Manufacturing, Digital Optical Technologies, Optical Metrology, and ECBO – the European Conferences on Biomedical Optics – from the latest research findings to innovative industrial applications.

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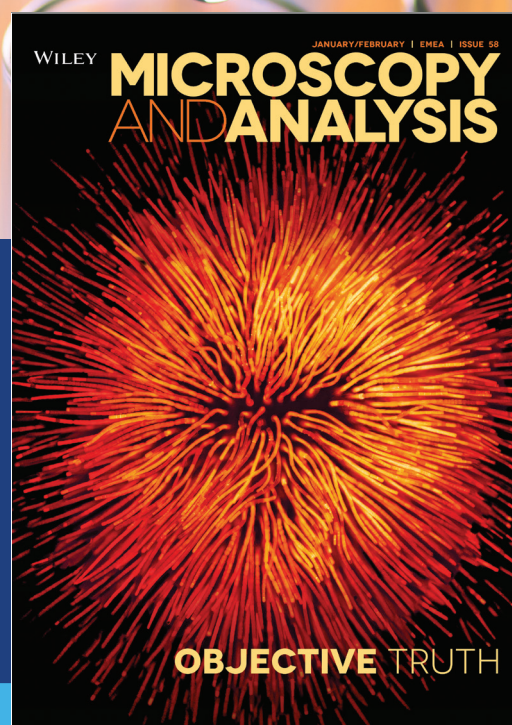
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Digital "E-Special" issue
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Focus: LaserEMobility Congress

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2

17 June 2025 Publishing date
08 May 2025 Advertising deadline
08 April 2025 Editorial deadline

Focus: Laser World of Photonics

- Laser systems
- Photonics for quantum technology
- Ultrashort-pulse lasers and applications
- ➔ with Company Profiles



D2

Digital "E-Special" issue
01 August 2025 Publishing date
15 July 2025 Advertising deadline
17 June 2025 Editorial deadline

Focus: Beam shaping

- Beam forming
- Beam combining
- Beam analysis

3

09 September 2025 Publishing date
04 August 2025 Advertising deadline
08 July 2025 Editorial deadline

- Laser welding, cutting, plastics processing
- Fibers and fiber optics
- Optical communication



4

11 November 2025 Publishing date
04 October 2025 Advertising deadline
09 September 2025 Editorial deadline

- Additive Manufacturing
- Medical applications
- Laser marking and engraving

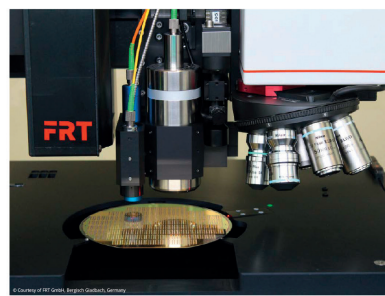


Beginning to see the light

Calculating the reflectance of semiconductors with vials

Michael Quinten

The reflectance of a semiconductor wafer changes if it is etched or patterned. This is a challenge for the calculation of the reflectance. The author presents a method to calculate the reflectance of a semiconductor wafer under consideration of the geometrical properties of the etched surface.



Photronics Views | e-special 01/2025

Technical Article

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

The image shows the horizontal E-Special layout.

High Precision Laser Cutting of Electrical Steel

Improved mechanics and laser synchronization provide a unique combination of precision, high overall throughput, and guaranteed part repeatability

Christian Brunschweiler



In the last cutting market, it is common to assume that laser power is the dominant factor in determining throughput. And when cutting through steel in which materials, especially at lower tolerances, higher power does indeed have great influence, there are many applications, especially in the automotive sector, where this is not the case.

Electrical steel is a highly magnetic material used in the construction of electric motors and generators. It is a soft magnetic material with high permeability and low coercivity. The material is used in the form of sheets or coils. The sheets are cut into various shapes and sizes using laser cutting technology. The laser cutting process is a non-contact process that allows for high precision and repeatability. The laser beam is focused on the material, creating a keyhole that is then removed by the laser beam. The resulting part is then cooled and finished.

Typically, laser cutting is used for the production of electrical steel parts. The laser cutting process is a non-contact process that allows for high precision and repeatability. The laser beam is focused on the material, creating a keyhole that is then removed by the laser beam. The resulting part is then cooled and finished. The laser cutting process is a non-contact process that allows for high precision and repeatability. The laser beam is focused on the material, creating a keyhole that is then removed by the laser beam. The resulting part is then cooled and finished.



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Product Report

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

The image shows the print layout, single page.



Edmund Optics, the premier provider of optical components, continuously expands its product offering to reflect rapid technological advances and customer needs. On a monthly basis, new products added to our catalog serve the industry's most demanding and most advanced applications. With this latest addition, Edmund Optics is proud to announce the release of its new product line, the Edmund Optics 100 Series.

The Edmund Optics 100 Series is a new line of optical components that are designed to meet the needs of the most demanding and most advanced applications. The Edmund Optics 100 Series is a new line of optical components that are designed to meet the needs of the most demanding and most advanced applications. The Edmund Optics 100 Series is a new line of optical components that are designed to meet the needs of the most demanding and most advanced applications.



Application Report

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

The image shows the print layout, double page.

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