

PhotonicsViews

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COVER STORY

AdheScan – adhesive failure surface inspection system



Partner of



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Flexible laser welding
as an addition to AM

OPTICS DESIGN

Creating advanced
photonics AI assistants

MACHINE VISION

The importance of image quality
in AI visual inspection systems

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Make it EPIC!

Driving Competitiveness of
European Photonics Industry
through an International Network

Pioneering the future of integrated photonics

The photonics industry is on the cusp of a transformative era, driven by the remarkable progress in photonic integrated circuits (PICs). The increasing adoption of PICs in data centers, where their speed and energy efficiency are indispensable, has propelled this technology forward. The surge in demand for artificial intelligence (AI) is further pressuring the semiconductor industry to explore alternative technologies, creating a significant opportunity for PICs.

As AI evolves, it demands massive computational power, pushing traditional semiconductor technologies to their limits. This has led to a growing interest in PICs, which not only offer better performance and lower energy consumption but also introduce new functionalities that enable the semiconductor industry to penetrate new markets. The volume demand for PICs, driven by data centers, accelerates the maturity of the PIC industry, paving the way for their deployment in high-impact applications like sensing and quantum computing.

However, realizing these opportunities requires global collaboration. Heterogeneous integration – combining diverse material systems onto a single chip – remains a significant challenge. Additionally, addressing critical issues such as standardization and testing is essential for ensuring the interoperability and scalability of PICs across various industries. These challenges necessitate a united effort, bringing together industry leaders, researchers, and innovators worldwide.

Central to this effort is the synergy between photonics and the semiconductor industry, like in the Integrated Photonics Systems Roadmap – International, IPSR-I, a global initiative led by MIT and PhotonDelta.

Yet, our vision extends beyond technology development. The success of PICs hinges on their integration into market-ready solutions in sectors like automotive, medical, datacom, and quantum computing. This requires deep partnerships with Tier-1 suppliers who understand the specific needs of these markets. PhotonDelta's expansion into Silicon Valley marks a significant milestone in this journey. Our new office will serve as a hub for collaboration, engaging key players in the North American region.

Our mission is clear: to drive the next wave of integrated photonics innovation by fostering global industry collaboration. By working together – across borders, disciplines, and industries – we can lay the foundation for tomorrow's groundbreaking applications.




Source: PhotonDelta

Jorn Smeets
Managing Director
North America
PhotonDelta
Foundation

 www.x.com/photonicviews

 www.linkedin.com/company/photonicviews

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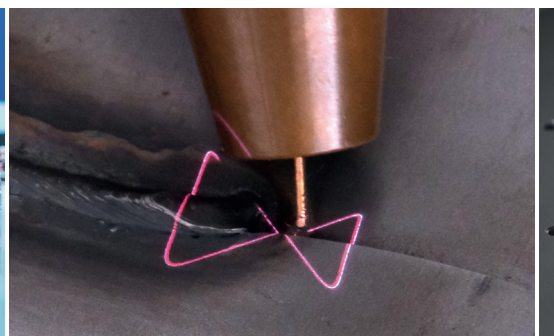
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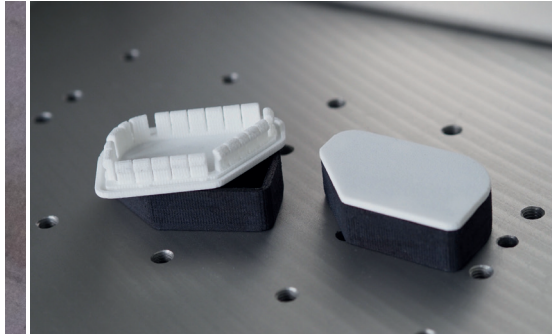
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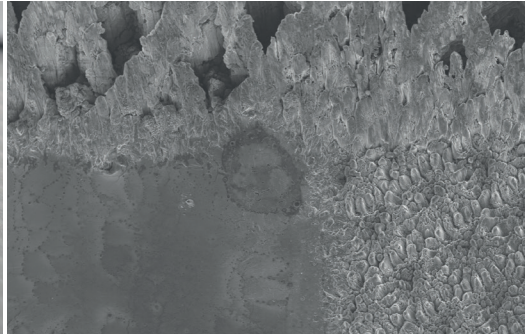
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COVER STORY
AdheScan – adhesive failure surface inspection system

Cover:

AdheScan – a complete inspection system for the machine learning assisted adhesive failure surface inspection. Shown here is the device in the preliminary housing, which will be also presented at the Vision 2024 show.

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Light technologies buck global trend, EU photonics shines

Industry leaders, researchers and policymakers debated the future of light technologies, including technological sovereignty and the need for resilient supply chains in Europe, at this year's annual meeting of Photonics21 in Brussels on the 14th and 15th of May

At a live discussion panel, 'Quo Vadis Photonics?', industry experts analyzed a wide range of photonics-related issues, including how the sector can contribute to policies such as the European Chips Act and technological sovereignty, international cooperation and partnerships for accelerating innovation, and strengthening the global competitiveness of the industry.

Keynote speakers, including Pierre Chastanet, head of unit for microelectronics and photonics, DG CNECT at the European Commission, and Michelangelo Masini, head of research and technology at Carl Zeiss, shared their insights to inform the strategic direction of photonics and its key role in driving innovation and economic growth. Kent Rochford, CEO and executive director of SPIE, provided a US and global perspective on the industry at the annual gathering.



Panel discussion with (l-r): Lutz Aschke – Photonics21 / Photonics Systems Group, Pierre Chastanet – EU Commission, Michelangelo Masini – Zeiss, Kent Rochford – SPIE, Ioanna Zergioti – PhosPrint (Source: Babylonla, Iris Haidau / Photonics21)

Photonics21 president Dr Lutz Aschke, CEO of Photonics Systems Group, said: "All photonics members from across the continent are welcome to share their critical insights into challenges and opportunities to drive the next wave of innovation over the next decade and come together to map out a path for groundbreaking technological and economic advancements."

A highlight of the event was the presentation of the latest worldwide photon-

ics market study, "Insights into the Dynamic Photonics Market (2019 – 2022)", which reveals the economic performance of photonics on a global scale.

According to the study conducted by the French market intelligence group Tematys, the photonics industries in Europe, Asia, and the US remained robust from 2019 to 2022 – a period plagued by some of the toughest global and economic tensions after decades of geoeconomics and globalization.

In Europe, the study shows employment surged by 35,000 jobs during this period, far exceeding the growth rate of EU manufacturing as a whole. At the same time, European photonics production soared to 124.6 billion euros in 2022, representing over 5,000 companies and contributing significantly to Europe's manufacturing landscape.

www.photonics21.org

Machine vision: VDMA issues negative growth forecast for the first time in 15 years

In 2023, turnover in the German and European machine vision industry fell by 7 %, reports the VDMA. The association is forecasting a decline of 3 % for 2024.

The machine vision industry in Europe has been reporting record sales for years. Between 2012 and 2022, turnover increased by an average of 9 % per year. Although sales fell by 4 % in 2020 due to the coronavirus pandemic, they shot up again in 2021 (plus 17 %) and 2022 (plus 11 %).

However, the combination of full customer warehouses – mainly caused by orders beyond demand – geopolitical risks and a weak global economy led to a 7 % drop in sales in 2023, both in Europe and Germany. The German machine vision industry still achieved a turnover of € 3.2 B.

"Unfortunately, due to the current economic and geopolitical situation, we were unable to match the records of previous years. Although we are seeing

initial improvements, it is unlikely that the European machine vision industry will return to growth before the end of 2024," comments Mark Williamson, chairman of the VDMA machine vision division.

Business expectations for 2024 deteriorated again in November and December 2023. As a result, the VDMA has issued a negative forecast for the first time since the economic crisis year of 2009: the association expects sales to fall by 3 % for 2024

as a whole. The reasons for this are the prevailing uncertainties, which are deterring machine vision users from investing. The machine vision industry's order backlog is shrinking accordingly.

However, from the second half of the year, at the latest in the run-up to the international Vision trade fair in Stuttgart (cf. p. 60), the tide should turn and some of the minus accumulated in the first half of the year should be offset.

www.vdma.com/vision

Hamamatsu acquires NKT

In early June, Hamamatsu Photonics KK has completed the acquisition of NKT Photonics A/S and now possesses a very broad range of technologies in light sources, lasers, and detectors. The combination of NKT Photonics and Hamamatsu Photonics will help to drive their technology to the next level, and accelerate our business growth in the semiconductor, quantum, and medical fields.

The acquisition enables Hamamatsu Photonics to combine its detectors and cameras with NKT Photonics' lasers and fibers, offer-

ing customers unique system solutions.

"We are very pleased to welcome NKT Photonics to the Hamamatsu group, where they will form the backbone of our laser division. By combining Hamamatsu's expertise within photodetectors with NKT Photonics' market-leading lasers and fibers, we will be able to provide unique system solutions to our core markets," said Hamamatsu CEO Tadashi Maruno.

One market of interest is the rapidly growing quantum computing area. Here NKT's Koheras lasers serve custom-

ers with trapped ion systems requiring high-power narrow linewidth lasers with extremely high wavelength stability and low noise. The same customers use Hamamatsu Photonics' high-sensitivity cameras and sensors to detect the quantum state of the qubits. Together we can provide comprehensive solutions for the quantum-technology market, including lasers, detectors, and optical devices.

"We are excited and honored to become part of Hamamatsu, one of the most respected global companies in our industry. We share



common goals and a vision of providing the best solutions to our customers and innovators. Together, and with our complementary technology platforms, we will be stronger than ever," said NKT CEO Basil Garabet.

NKT Photonics will maintain its operating structure.

www.hamamatsu.com

www.nktphotonics.com

AMS Osram sells assets to Focuslight Technologies

For 45 million euros in cash, the group based in Austria and Germany sells relevant passive optical components assets to the fast-growing Chinese optical technology company. The transaction is expected to close in third quarter 2024.

"With our strategic efficiency program 'Re-establish

the Base', we have promised as one key element to exit the non-core portfolio in our semiconductor business. Now we deliver another important step and announce the sale of relevant passive optical components assets to Focuslight Technologies Inc, who is an excellent home for them. AMS Osram continues

executing its 'Re-establish the Base' program according to plan," said Aldo Kamper, CEO of AMS Osram.

Focuslight agreed to acquire those assets. The transaction is subject to closing conditions which include approvals by the Focuslight shareholders and Chinese regulatory authorities.

The existing AMS Osram business in optical components for consumer applications, generating around 50 million euros of revenues in 2023 and phasing out in 2024, is not part of the transaction.

<https://ams-osram.com>

www.focuslight.com

Inrad Optics and PLX are now a part of Luxium Solutions

Headquartered in Hiram, Ohio, Luxium creates crystal scintillation materials as well as sapphire and garnet substrates for photonics and power electronics. Formerly known as Saint-Gobain Crystals, it is an affiliate of private equity firms SK Capital Partners and Edgewater Capital Partners. It has now acquired PLX Inc and PLX UK Ltd from an investor group led by Tinicum, and has also agreed to acquire Inrad Optics Inc in an all-cash transaction that values Inrad at approximately \$19 M, including assumed debt.

Under the terms of the definitive merger agreement, Luxium has agreed to acquire all issued and

outstanding shares of Inrad Optics common stock, including common stock underlying its \$2.5 M convertible notes and in-the-money stock options, for \$1.10 per share in cash.

Following the closing of the transaction, the ultra-high precision optical components company expects to benefit from the significant resources, operational expertise and capacity for investment provided by Luxium, SK Capital and Edgewater.

"As a part of a private company, we will have enhanced flexibility and additional financial resources to build on Inrad Optics' strong foundation, further scale operations, and capture significant oppor-

tunities in rapidly growing markets," said Amy Eskilson, CEO of Inrad Optics.

The addition of PLX broadens Luxium's offering of detection-enabling technologies by enhancing its suite of photonics assembly solutions which are complemented with high-end optical engineering and design services. PLX's solutions are deployed in a range of harsh environments and high-end applications where structural integrity and accuracy over time are critical, such as military fire control systems, bore sighting, beam alignment and delivery systems, laser tracking, environmental monitoring, metrology, and satellite ranging. PLX's proprietary and patented

monolithic optical structure technology (MOST) integrates complex optical elements into compact monolithic structures, achieving exceptional accuracy and stability under severe environmental conditions.

"We believe Luxium is the right partner for PLX in its next phase of growth. Luxium and PLX share a strong alignment in their go-to-market strategies emphasizing collaboration with customers to develop customized solutions," said Itai Vishnia, CEO of PLX, who will continue to lead the PLX group within the Luxium portfolio.

www.inradoptics.com

www.luxiumsolutions.com

www.plxinc.com

Zeiss expands its Innovation Hub in Dresden, establishes new Photonics & Optics division



Source: Zeiss
Dr Kai Wicker (Zeiss ZIH), Prof Dr Ursula Staudinger (TU Dresden), Dr Karl Lamprecht (Zeiss)

In a partnership with the Technical University Dresden, the enterprise moves into new premises to further expand research activities in the life sciences and health sector. The new premises of the Zeiss Innovation Hub Dresden opened on

7 May. The new area offers the twelve employees more room for additional innovation projects and the opportunity for further growth. The team is moving from the premises in the building of the Else Kröner Fresenius Center (EKfZ) on

the campus of the Carl Gustav Carus University Hospital, directly opposite the campus. ZIH Dresden has around 700 square meters of floor space and modern laboratories, which the Innovation Hub employees will share with teams from Zeiss Microscopy.

New strategic business

With effect from the next fiscal year, Zeiss will establish a new strategic business unit within the Zeiss group: 'photonics and optics' bundles smaller, existing businesses outside the Zeiss divisions that have growth potential and for which Zeiss is the suitable owner. André Kutz, currently head of strategy, and Dr Bernhard Ohne-

sorge, managing director of the group's production company, will take over management of the BU.

The units of the consumer products strategic business unit will move to photonics and optics: cinematography, mobile imaging including brand partnerships and photo as well as the optics business for hunting and nature observation. From the Zeiss group's production company, micro-optics, spectroscopy, planetarium and simulation projection solutions will move to the new strategic business unit. The combined annual sales of the combined units are around € 200 M with almost 900 employees worldwide.

www.zeiss.com

ILT joins Labsphere, partners with SphereOptics

A new strategic partnership includes International Light Technologies (ILT) devices in SphereOptics' product range. This strategic partnership will expand SphereOptics' optical measurement solutions product.

ILT is a renowned manufacturer of light measurement devices and solutions with over fifty years of industry experience and is now part of Labsphere Inc, an existing supplier to

SphereOptics. Through the collaboration, SphereOptics can now offer its customers an even broader range of highly precise and reliable light measurement devices.

"This collaboration enables us to deliver innovative and high-quality products that meet our customers' demands for precision and reliability. ILT brings extensive expertise and state-of-the-art technology, providing significant bene-

fits to our customers," says SphereOptics' managing director Dr Rainer Böhm.

The new product line includes a variety of compact light measurement devices, such as radiometers and spectroradiometers, which are used in various industries including lighting, printing, medical technology, and research. With these new products, SphereOptics can offer customized solutions tailored to the spe-

cific needs and requirements of its customers.

ILT had announced its integration with Labsphere on 2 April 2024. As a division of the 1979-founded photonics company, ILT retains its name and brand but can use Labsphere's global distribution network, manufacturing partnerships, and engineering prowess.

www.sphereoptics.com

<https://internationallight.com>

www.labsphere.com

Menlo Systems' new offices in China, USA



Source: Menlo Systems
Menlo Systems Inc., 6205 Lookout Rd, Unit D, Boulder, CO 80301, USA

The Chinese subsidiary of the German company Menlo Systems from Munich has

completed the transfer to their new office space end of May. The new location in the same building comes with a tripled area, offering generous room for an inviting work environment, with a conference area to welcome visitors, and also laboratory space for testing and maintenance of the Menlo products in China.

The opening of the new premises in Shanghai express the company's commitment to enhance and extend its

service and support for Chinese customers and partners. Overall, the relocation is part of its plan to expand the global presence to best serve the growing photonics markets.

To achieve that, the US subsidiary, Menlo Systems Inc, moved its headquarters from its longtime home in Newton, New Jersey, to Boulder, Colorado. The new facility doubles the square footage of the previous location and reflects

the company's commitment to customer support, innovation, and growth.

While the office portion of the building is already in use, construction will take place to build out lab and warehouse space providing the required infrastructure to support development, production, and expanded service capabilities. The official opening of the premises is planned for the second half of 2024.

www.menlosystems.com

Cleanroom facility for lens assembly

Resolve Optics opens new cleanroom facilities at its Chesham, UK headquarters. The investment provides an ISO 6 clean room (Class 1000) environment within the work areas used for assembly of lenses, optical systems, and modules.

Mark Pontin, managing director of Resolve Optics said “We are constantly looking at ways of improving our product quality. As part of this ongoing program of continuous improvement we have just completed a major refurbishment of our clean room. In addition to installing a new, higher specification air circulation / filtration system, we have also installed new optical assembly benches with easy clean surfaces throughout the production facility. Through investing in a better, cleaner area we are looking to fur-

ther improve the quality of lenses and optical systems to comply with the most demanding requirements of customers in the aerospace, defense, medical and nuclear industries.”

He added: “Key to the quality of the lenses and optical systems we produce is our skilled and experienced team. Extensively trained and with a keen understanding of the delicacies of optical assembly, our team ensures that every component assembled in our cleanroom facility meets strict quality requirements. The new cleanroom area also provides a particulate free environment for the final inspection of products. This ensures that all lenses and optical systems leave Resolve Optics in the best possible condition.”

www.resolveoptics.com

Onsemi acquires SWIR Vision Systems

SWIR Vision Systems will become a wholly owned subsidiary of Onsemi and its workforce will be integrated into the company’s intelligent sensing group. The team will continue to be based in North Carolina. Integrating the patented shortwave infrared (SWIR) colloidal quantum dot (CQD) into Onsemi’s industry-leading sensors will significantly expand the company’s intelligent sensor product portfolio and pave the way for further growth in key markets such as industrial, automotive and defense.

CQD uses nanoparticles or crystals with unique optical and electronic properties that can be precisely tuned to absorb an extended wavelength. This extends the visibility and detection of systems beyond the range of standard CMOS sensors to SWIR wavelengths. To date, SWIR technology has seen

limited adoption due to the high cost and manufacturing complexity of the traditional indium gallium arsenide process. With this acquisition, Onsemi will combine its silicon-based CMOS sensors and manufacturing expertise with CQD technology to deliver highly integrated SWIR sensors at lower cost and in higher volumes.

These advanced SWIR sensors can see through dense materials, gases, fabrics and plastics, which is essential in many industries, especially industrial applications such as surveillance systems, silicon inspection, machine imaging, food inspection, and autonomous vehicle imaging, the higher spectra provide better visibility to see through difficult conditions such as extreme darkness or dense fog or winter glare.

www.onsemi.com
www.swirvisionsystems.com

Maxphotonics opens Business, Service & Innovation Center Europe

The Chinese laser manufacturer has opened its new European headquarters in Gilching near Munich, underlining the company’s commitment to the European market. In addition to replacement lines available directly on site, a center for innovation and training is also being built in Gilching. Here, customers and partners will have the opportunity to familiarize themselves with the latest laser technologies from the company and receive further training in practical courses. In addition, an experienced team of sales and service experts will be on hand to provide customers with help and advice.

The laser manufacturer was founded in 2004 and is headquartered in Shenzhen, China. The company specializes in the research and



Maxphotonics’ new European headquarters in Gilching near Munich, Germany

Source: Maxphotonics

development, production and sale of high-power fiber lasers with up to 85 kW, suitable for welding and cutting.

The product portfolio essentially comprises cw and pulsed fiber lasers as well as mobile laser welding systems. All offer a very good watt-per-euro ratio and are primarily used in mechanical engineering and the automotive industry.

<https://en.maxphotonics.com>

Physik Instrumente opens technology hub

On July 17, 2024, Physik Instrumente (PI) inaugurated the PI Technology Hub in Karlsruhe, Germany. On an area of 500 square meters, the hub offers space for ten employees of the central department ‘global research’ as well as ten additional places for more extensive project work and for PhD students and working students. It is equipped with special laboratories to allow for hands-on experiments. The strategic proximity to the Karlsruhe Institute of Technology (KIT) and other research institutions will promote an intensive exchange and close cooperation.

“The Technology Hub will bring together the latest findings from basic research with decades of practical experience in the global high-tech industry,” says Salah Benamira, SVP global research of PI. For more than

fifty years, the company has been a leading supplier of products and systems that perform motion to within a millionth of a millimeter.



Salah Benamira, SVP global research at PI, welcoming the guests

Source: PI/Robert Fuge

The focus of the PI Technology Hub is on the further development of existing drive technologies to significantly increase positioning accuracy and dynamics, as well as the development of new, innovative drive principles, including mechanics, sensors, metrology, and electronics to algorithms and software.

www.physikinstrumente.com

Coherent appoints Jim Anderson as CEO



Jim Anderson (Source: Coherent, courtesy of Lattice Semiconductors)

Following a comprehensive search, Coherent's board of directors has appointed Jim Anderson as the company's new CEO, effective 3 June 2024.

Jim Anderson joins Coherent from Lattice Semiconductors, where he was president, CEO, and a member of its board of directors. He succeeds Dr Vincent 'Chuck' Mattera, who, as previously reported, is retiring as chair and CEO of

Coherent. Mr Anderson also joins the company's board of directors.

Prior to joining Lattice in 2018, Mr Anderson was senior vice president and general manager of Advanced Micro Devices' computing and graphics business group. He previously held leadership positions in general management, engineering, sales, marketing, and strategy at companies including Intel, Broadcom (formerly Avago Technologies), and LSI Corporation.

Mr Anderson holds an MBA and an MSc in electrical engineering and computer science from MIT, an MSc in electrical engineering from Purdue University, and a bachelor's degree in electrical engineering from the University of Minnesota.

www.coherent.com

New sales director joins Blackbird management team

Blackbird Robotics is growing its leadership team and creating a new area for business field development. Longstanding sales director Thibault Bautze-Scherff will focus on targeting new business fields. This puts him in a leading role in terms of the company's strategic growth.

Benjamin Bopp (43) is stepping in to fill the gap in

the role of global sales manager starting in April. From his previous work as an application engineer specializing in laser welding, Bopp brings a wealth of professional expertise in technical consultancy. Besides this he gained more than 15 years of experience in international sales from his former roles.

www.blackbird-robotics.de



(l-r) Thibault Bautze-Scherff, Benjamin Bopp, Karl Christian Messer (Source: Blackbird Robotics)

Leadership change at Smaract

From startup to an internationally successful corporate group – with continuous growth, the demands on the role of management of the Smaract group have significantly changed. This development has led Axel Kortschack to place the leadership in the hands of the long-time manager Michael Weigel-Jech.

"A few years ago, we at SmarAct decided to take new paths. With small, interdisciplinary, and semi-autonomous teams, we have reduced bureaucracy and increased our agility and customer proximity. This has worked excellently," explains Kortschack. The next challenge is for all teams to master the balance between quick, uncomplicated work and adherence to stabilizing agreements, so that the company can continue to grow together with its customers.

Michael Weigel-Jech, who knows the company and its customers very well through



Source: Smaract

Michael Weigel-Jech

his long-standing affiliation and various leadership roles, has shown that he consistently motivates his teams to develop further and do their best in the common interest. These are ideal conditions to take on the tasks of managing the company.

"Axel has guided the company from a startup through its formative early stages and now through a somewhat stormier adolescence to a corporate group with three independent business units. We are all very grateful for that," emphasizes Weigel-Jech.

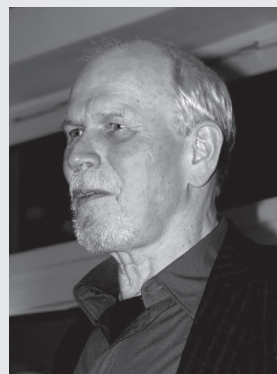
www.smaract.com

In memoriam Gregor Federau

The long-standing owner and managing director of Schäfter+Kirchhoff passed away at the age of 83 on July 8, 2024.

In 1976, Mr Federau took over the engineering firm founded by the two optical engineers Paul Schäfter and Kurt Kirchhoff and subsequently shaped the fortunes of the company for decades with his entrepreneurial vision and flair for high-quality technical solutions. In 2016, he established the non-profit Gregor Federau Foundation and contributed Schäfter+Kirchhoff GmbH to the foundation's assets.

As someone who did not have it easy in his younger years, it was important to



Source: Schäfter+Kirchhoff

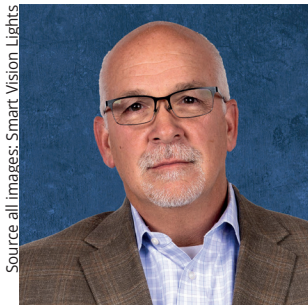
Gregor Federau, †2024

him to help young people make a successful start to adult life despite difficult circumstances.

The staff and management of Schäfter+Kirchhoff have pledged to continue his work in his spirit and honoring his memory.

www.sukhamburg.com

Smart Vision Lights announces leadership transition



Dave Spaulding

Dave Spaulding will retire as president and CEO at the end of 2024. Steve VanderZwaag, currently serving as vice president of engineering, will step into the role of effective January 1, 2025.



Steve VanderZwaag

During his twelve-year tenure, Dave Spaulding has propelled Smart Vision Lights to the forefront of the machine vision lighting industry. Under his guidance, the company expanded

into new markets and solidified its reputation. His leadership significantly increased the company's market share and revenue.

Steve VanderZwaag joined Smart Vision Lights in 2020, initially leading the development and launch of the new electronic assembly department. Promoted to vice president of engineering in 2023, Steve brings over 25 years of diverse business experience, including key leadership roles in engineering and quality departments.

<https://smartvisionlights.com>

Former Mercedes top executive joins Scantinel

With Zeiss Ventures, Scania Growth Capital, and Photon-Venture already supporting the company, Scantinel now has the backing of another prominent figure in the automotive industry. Frank Lindenberg, who was a member of the Mercedes-Benz board of management as CFO and head of corporate strategy, has joined.

Previously, Lindenberg served as CFO of Daimler Trucks and held various management positions across multiple business units and central functions

within the Daimler group. Since leaving Mercedes-Benz in 2020, Lindenberg has been active as a consultant and investor in startups and venture capital. He also served on the board of directors of the American electric car manufacturer Lucid from 2021 to 2023. Lindenberg brings over thirty years of experience in the automotive industry and has insights into startups and venture capital.

CEO Dr Michael Richter adds: "The appointment of Frank Lindenberg as chair-



Frank Lindenberg

man of the advisory board marks an important milestone for our company."

www.scantinel.com

Dietmar Kracht receives professorship at Hanover University

The executive director of Laser Zentrum Hannover (LZH), Dr Dietmar Kracht, has accepted the call to become a university professor of applied laser physics at Leibniz University Hannover (LUH) and the LZH as of 1 May, 2024.

"At LZH, we conduct research in cutting-edge fields of applied laser physics," says Dietmar Kracht. "I am excited to bring this expertise to the next generation of scientists in my new role as a university professor."

The newly established professorship is located at the faculty of mathematics and physics. Dr Kracht has been lecturing in laser physics at LUH since 2007.

Kracht studied physics at Christian Albrecht University in Kiel, Germany. He received his doctorate in 2003 from the University of Lübeck. Since 2002, he has been working at LZH, first as a project leader. From 2004 to 2005, he was head of the solid-state photonics group, and then head of the laser development



Dr Dietmar Kracht

department until 2008. Dietmar Kracht has been scientific technical director of LZH since 2008 and was appointed as the executive director in 2009.

www.lzh.de

ALSO OF INTEREST

On-the-fly laser welding for more efficient, lower-cost production

Blackbird's open house event attests to robust industry interest

Eyesight from a 3D printer

KIT, Zeiss, and Evonik develop process for printing personalized corneas; project wins "Neuland" innovation contest

ERC funding for novel spectral filters

Malte Gather receives 150,000 euros to explore the commercial or societal potential of the research project

Vision & Control and Piezosystem Jena become partners for America

The two strategic partners want to enter the American market with combined powers

Toptica appoints Acexon as partner for Singapore

Strategic collaboration is set to enhance laser photonics company's market presence across the South East Asia region

MVtec and Mitsubishi Electric work more closely together

The two companies are strengthening their cooperation as part of MVtec's technology partner program

Specialized Imaging establishes CMOS image sensor division

Philip Brown, leads the newly formed 'SI Sensors' team with experience in image sensor design

New Infratec building completed

The new extension building in Dresden reached its finalization in spring 2024 after less than two and a half years

Edmund Optics focuses on sustainability

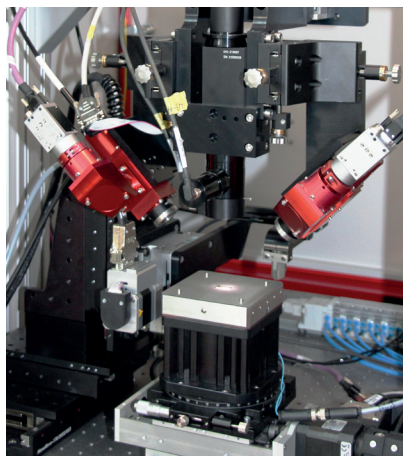
The company has launched a website on the topic

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Wiley Industry News
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Stable fiber assembly methods for quantum computing silicon photonics chips



Manufacturer: Nanosystec

Product: VersaSolder non-contact joining system

Features: VersaSolder uses selective laser soldering for applications where other methods fail. A laser beam heats an area without impacting the surrounding – the key advantage of this non-contact joining technique. The VersaSolder System offers two selective laser soldering technologies: laser and hot bar soldering. Depending on the workpieces and process flow, both methods can be combined in one station. Powerful machine vision and automated loading concepts provide the foundation for fully automated processing.

Applications: Silicon photonics chips for quantum computing operate at a tem-

perature of a few Kelvin. This makes the attachment of the necessary single mode fibers challenging. The typical epoxy gluing method does not create stable connections, especially when several cool-down cycles are needed. Selective laser soldering provides much more robust connections which survive repetitive temperature cycling. The VersaSolder system is ideally suited to connect multiple optical fibers with this type of silicon photonics chips.

nanosystec GmbH

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Web: www.nanosystec.com
Meet us at: ECOC, Booth #C18

Micropositioning systems and optomechanical components

Manufacturer: Owis

Product: Standard optomechanical components and positioners that can be used to simplify scientific experiments and build customer-specific applications. They are of the highest quality and always optimally aligned to the workpiece and the machining process.

Features: The "Optics box" is nothing more than a laboratory setup optimized for industrial series production, assembled, adjusted and delivered as a

high-quality plug-and-play system. The company's engineers provide design support, minimize size and costs and optimize the selection of components and materials.

By cleverly combining standard components, there are customer-specific multi-axis systems for free positioning on up to nine axes. They enable workpieces, tools or lasers to be positioned freely in space.

Applications: Typical examples include laser processing, sensor technology,

analytics, medical technology, semiconductor technology and clean room applications in general.

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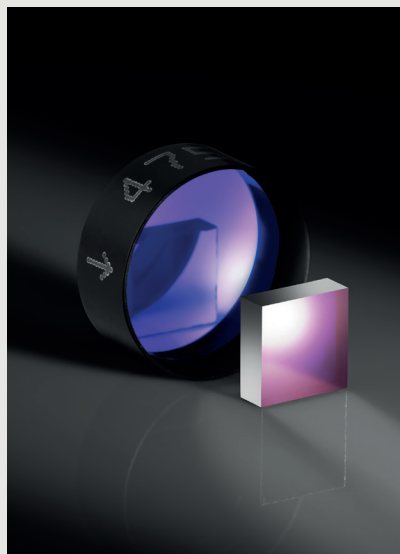
Product of the Month

Fluorescence bandpass filters off the shelf

Manufacturer: Edmund Optics

Product: New 'DLPVA-101-B', '-F' and hard-coated interference filters with a superior blocking (optical density ≥ 8) in their blocking band while offering high transmission in their transmission band. As an industry first, the filters are in stock and ready to ship.

Features: The filters excel with high-precision spectral consistency and enable industry-leading signal-to-noise system performance and low crosstalk. They are designed with passbands for the fluorescence excitation and emission of common qPCR fluorophores in mind, namely FAM, HEX, ROX and Cy5. The filters are available in black anodized aluminum mounts



or unmounted in 6×6 mm wafers for easy system integration.

Applications: OD8 fluorescence bandpass filters are ideal components in applications relying on fluorescence detection that require precision spectral clean-up, such as biomedical diagnostics instruments including DNA sequencers and polymerase chain reaction (PCR) analyzers.

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Miniaturizing a laser on a photonic chip

A tiny powerful fiber laser on a silicon-nitride chip promises advances in optical communications

Erbium-based fiber lasers are interesting, as they meet all the requirements for maintaining a laser's high coherence and stability. But miniaturizing them has been met by challenges in maintaining their performance at small scales. Now, scientists led by Yang Liu and Tobias Kippenberg at EPFL have built the first ever chip-integrated erbium-doped waveguide laser that approaches the performance with fiber-based lasers, combining wide wavelength tunability with the practicality of chip-scale photonic integration.

The researchers developed their chip-scale erbium laser using a state-of-the-art fabrication process. They began by constructing a meter-long, on-chip optical cavity based on ultralow-loss silicon nitride photonic integrated circuit.

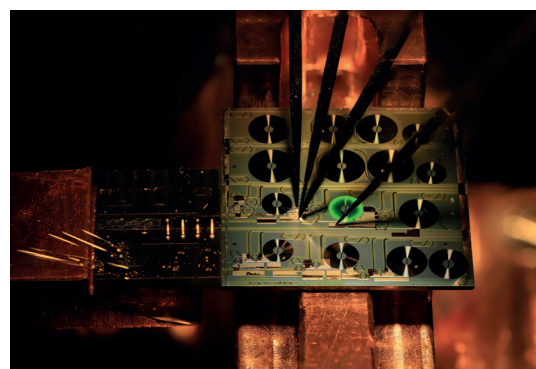
The team then implanted the circuit with high-concentration erbium ions to selectively create the active gain medium necessary for lasing. Finally, they integrated the circuit with a III-V semiconductor pump laser to excite the

erbium ions to enable them to emit light and produce the laser beam.

To refine the laser's performance and achieve precise wavelength control, the researchers engineered an innovative intracavity design featuring microring-based Vernier filters for dynamic wavelength tuning over a broad range. This design supports stable, single-mode lasing with an impressively narrow intrinsic linewidth of just 50 Hz.

The chip-scale erbium-based fiber laser features output power exceeding 10 mW and a side mode suppression ratio greater than 70 dB, outperforming many conventional systems. It also has a very narrow linewidth. The Vernier filter gives the laser broad wavelength tunability across 40 nm within the C- and L-bands, surpassing legacy fiber lasers in both tuning and low spectral spurs metrics, while remaining compatible with current semiconductor manufacturing processes.

Miniaturizing and integrating erbium fiber lasers into chip-scale devices can



Source: Y. Liu, EPFL

Image of a hybrid integrated erbium-doped photonic integrated circuit-based laser

reduce their overall costs, making them accessible for portable and highly integrated systems across telecommunications, medical diagnostics, and consumer electronics. (Source: EPFL)

Y. Liu et al.: A fully hybrid integrated erbium-based laser, *Nat. Phot.*, online 10 June 2024, DOI: 10.1038/s41566-024-01454-7

www.epfl.ch/research/domains/quantum-center

3D-printing of microscale photonic lantern multiplexers

New approach opens opportunities for spatial mode multiplexing

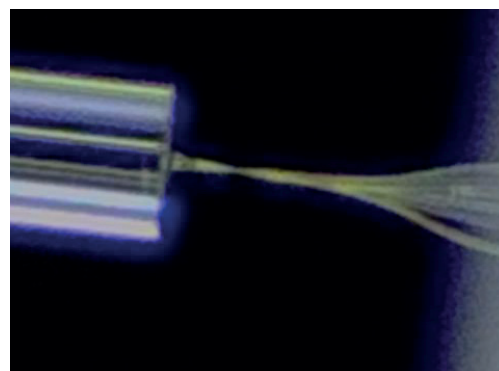
Optical waves propagating through air or multimode fiber can be patterned or decomposed using orthogonal spatial modes, with far-ranging applications in imaging, communication, and directed energy. Yet the systems that perform these wavefront manipulations are cumbersome and large, restricting their utilization to high-end applications. The development of a "free-standing microscale photonic lantern spatial mode (de-)multiplexer using 3D nanoprinting", is presented as a significant advancement in photonic technology.

This spatial multiplexer, characterized by its compactness, minimal footprint, and ability to directly print on, and adhere to, photonic circuits, optical fibers, and optoelectronic elements as lasers and photodetectors, opens new opportunities in system integration and adoption of the technology in future high-capacity communication systems and demanding imaging modalities.

The work of Yoav Dana, Dan Marom and his team at the Hebrew University of Jerusalem, in partnership with scientists from Nokia Bell Labs, resulted in the development and demonstration of the new microscale photonic lantern. The device was fabricated by a 3D nanoprinting technique utilizing direct laser writing, applied directly onto an optical fiber tip.

Photonic lantern devices convert between optical waves containing a superposition of modes or distorted wavefronts and array of separated single-mode optical signals. The technology stands out as a promising contender to enable space division multiplexing (SDM) in high-capacity future optical communication networks, as well as in imaging and other applications requiring the spatial manipulation of optical waves.

Harnessing the capabilities of 3D nanoprinting and employing high-index contrast waveguides, the researchers have developed a compact and versatile



Source: NPG / HUJI, Dan Marom

SEM image of photonic lantern structure with a supporting frame

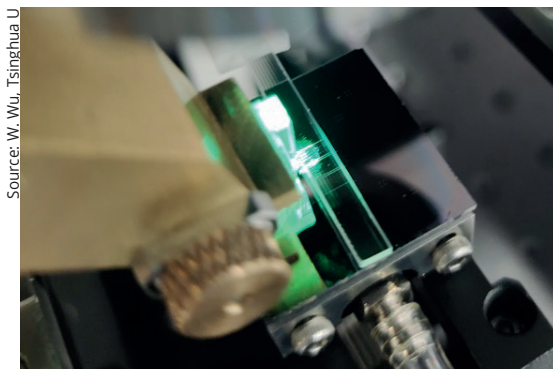
device that can be printed onto nearly any solid platform with fine accuracy and high fidelity. (Source: HUJI)

Y. Dana et al.: Free-standing microscale photonic lantern spatial mode (De-)multiplexer fabricated using 3D nanoprinting, *Light: Sci. Appl.* 13, 126 (2024); DOI: 10.1038/s41377-024-01466-6

<https://scholars.huji.ac.il/danmarom>

Photonic chip integrates sensing and computing

Technology eliminates optical-electronic conversions for ultrafast machine vision



Light being focused through the microlens array onto the microring in the OPCA chip test system

Researchers have demonstrated a new intelligent photonic sensing-computing chip that can process, transmit and reconstruct images of a scene within nanoseconds. This advance opens the door to extremely high-speed image processing that could benefit edge intelligence for machine vision applications such as autonomous driving, industrial inspection and robotic vision.

Edge computing, which performs intensive computing tasks like image

processing and analysis on local devices, is evolving into edge intelligence by adding artificial intelligence (AI) driven analysis and decision-making. “Capturing, processing and analyzing images for edge-based tasks such as autonomous driving is currently limited to millisecond-level speeds due to the necessity of optical-to-electronic conversions,” said team leader Lu Fang from Tsinghua University in China. “Our new chip can perform all these processes in just nanoseconds by keeping them all in the optical domain. This could be used to significantly enhance, or even replace, the traditional architecture of sensor acquisition followed by AI postprocessing.”

The researchers call it an optical parallel computational array (OPCA) chip. They show that the OPCA has a processing bandwidth of up to one hundred billion pixels and a response time of just 6 ns, which is about six orders of magnitude faster than current methods. They also used the chip to create an optical neural network that integrates

image perception, computation and reconstruction.

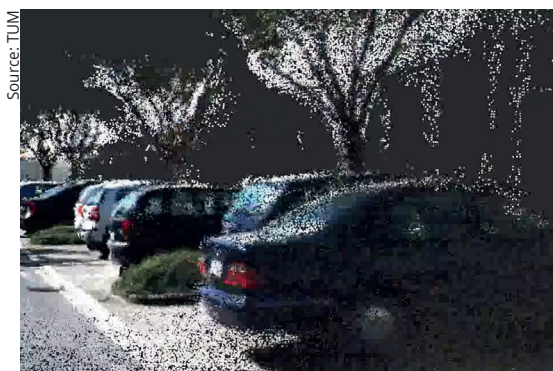
The challenge in performing both image acquisition and analysis on the same chip in the optical domain is finding a way to convert the free-space spatial light used for imaging into an on-chip guided light wave. The researchers achieved this by designing a chip that consists of a sensing-computing array of dedicated designed ring resonators that convert a free-space optical intensity image into a coherent light signal that can then be guided on the chip. A microlens array enhances the process by focusing the scene onto the OPCA chip. For practical use, the optical neural network’s processing capacity would need to be increased to handle increasingly complex and intelligent tasks. (Source: Optica)

W. Wu et al.: Parallel photonic chip for nanosecond end-to-end image processing, transmission, and reconstruction, *Optica* 11, 831 (2024); DOI: 10.1364/optica.516241

www.ee.tsinghua.edu.cn

From two images to a 3D object

More precise 3D reconstructions for autonomous driving and preservation of cultural artefacts



Fields of application for 3D reconstructions include autonomous driving and monument conservation

In recent years, neural methods have become widespread in camera-based reconstructions. In most cases, however, hundreds of camera perspectives are needed. Meanwhile, conventional photometric methods exist which can compute highly precise reconstructions even from objects with textureless surfaces. However, these typically work only under controlled lab conditions.

Daniel Cremers from the Technical University Munich TUM has developed a method together with his team that utilizes the two approaches. It combines a neural network of the surface with a precise model of the illumination process that considers the light absorption and the distance between the object and the light source. It combines a neural network of the surface with a precise model of the illumination process that considers the light absorption and the distance between the object and the light source. The brightness in the images is used to determine the angle and distance of the surface relative to the light source.

“That enables us to model the objects with much greater precision than existing processes. We can use the natural surroundings and can reconstruct relatively textureless objects for our reconstructions,” says Cremers. The method can be used to preserve historical monuments or digitize museum

exhibits. If these are destroyed or decay over time, photographic images can be used to reconstruct the originals and create authentic replicas.

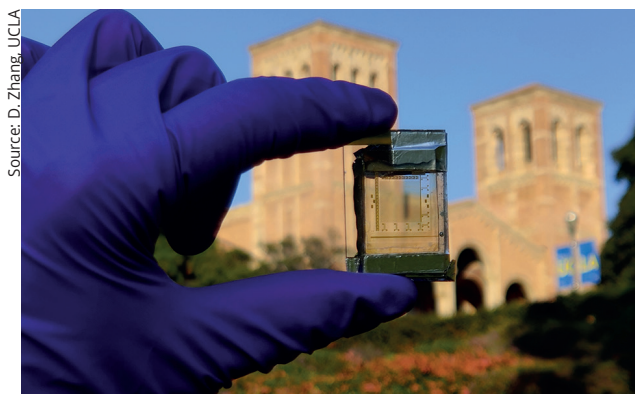
The team also develops neural camera-based reconstruction methods for autonomous driving, where a camera films the vehicle’s surroundings. The autonomous car can model its surroundings in real time, develop a three-dimensional representation of the scene, and use it to make decisions. The process is based on neural networks that predict 3D point clouds for individual video images that are then merged into a large-scale model of the roads travelled. (Source: TUM)

M. Brahimi et al.: Sparse Views Near Light: A Practical Paradigm for Uncalibrated Point-light Photometric Stereo, *Proc. IEEE/CVF Conf. Computer Vision and Pattern Recog. (CVPR)*, 11862 (2024); DOI: 10.48550/arXiv.2404.00098

<https://mcml.ai/research/areab/#b1>

Light-based computing for future smart cameras

New device demonstrates ability to reduce glare in images



Source: D. Zhang, UCLA

The new experimental device uses a 2D semiconductor material

To date, photonic computing has faced a limitation in achieving nonlinear responses, which means producing signals not directly proportional to the input. Nonlinearity makes universal computing applications, including artificial intelligence, possible.

Nonlinear materials and devices under development need a substantial amount of light to work. Previously, this required high-powered lasers that operate only in a narrow band of the electromagnetic spectrum, absorbing light over time – making processing slow, or using energy-inefficient materials that take in lots of light but preclude applications that require light efficiency or transparency. Now, a recent collaborative study from members of the California Nano-Systems Institute CNSI at the University of California Los Angeles has introduced a device that overcomes these hurdles.

In a major step toward optical computing for processing visual information, the investigators showed that a tiny array of transparent pixels could produce a fast, broadband, nonlinear response from low-power ambient light. The team also demonstrated an application that combines their device with a smartphone camera to reduce glare in images. Aydogan Ozcan explained “We need low-power, broadband, low-loss and fast nonlinearities for optical systems to meet our visual computing needs. This work helps fill that gap.”

Potential applications for the technology – beyond the glare reduction validated in the study – cross a variety of consumer and industrial uses: improved sensing for autonomous vehicles; cameras that recognize cer-

tain objects while hiding others; image encryption; and efficient, effective detection of defects in robotic assembly lines, among many others.

The device could offer many advantages. For example, the incoming images could be processed without conversion to a digital signal, speeding results and reducing the amount of data being sent to the cloud for digital processing and storage. The researchers envision linking their technology with cheap cameras and compressing data to produce images with vastly higher resolution than was realized before, and more precisely and accurately capturing useful information about the arrangement of objects in space and the electromagnetic spectra present in the light.

The device in the study is a transparent plane measuring 1 cm². It uses a 2D semiconductor material that was developed by Xiangfeng Duan from the UCLA College. The thinness of the material makes it transparent, while it retains qualities that enable incoming photons to efficiently regulate electrical conductivity. The research team coupled the 2D semiconductor with a layer of liquid crystal and made it functional with an array of electrodes. The result is a smart filter comprising ten thousand pixels, each able to selectively and quickly darken in a nonlinear way when exposed to broadband ambient light. (Source: UCLA)

D. Zhang et al.: Broadband nonlinear modulation of incoherent light using a transparent optoelectronic neuron array, *Nat. Commun.* 15, 2433 (2024); DOI: 10.1038/s41467-024-46387-5

<https://cnsi.ucla.edu>

ALSO OF INTEREST

Polarons for a faster and secure future of telecom

New approach could unveil energy-efficient information processing and sophisticated data security

More efficient data transfer in data centers

Researchers combine nonlinear predistortion and digital resolution enhancement to overcome DAC challenges

Photon pairs interfere with a twist

Stabilizing the interference of two photons in optical chips

Scaling advantage of quantum computers

Besch Theoretical quantum speedup with the quantum approximate optimization algorithm

Optical neural networks for AI imaging

A new ultrafast and high energy-efficient optical machine learning platform for graphic processing

New way to fabricate optical qubits in silicon

A programmable approach to produce qubits for large-scale manufacturing

99 % usable area on 100 mm bulk aluminum nitride substrate achieved

Crystal IS and Asahi Kasei improve wafer quality based on specification for UVC LED

An improved cutting process for battery separator foils with CO₂ lasers

Laser manufacturer Luxinar is highlighting the benefits of laser cutting battery separator foils at the LaserEMobility Workshop

Quantum optical antennas in solids

New devices could provide more powerful measurements on the atomic level

Unifying microscopy and spectral analysis workflows

Release of the end-to-end software solution Wiley Surface-to-Spectral Analysis

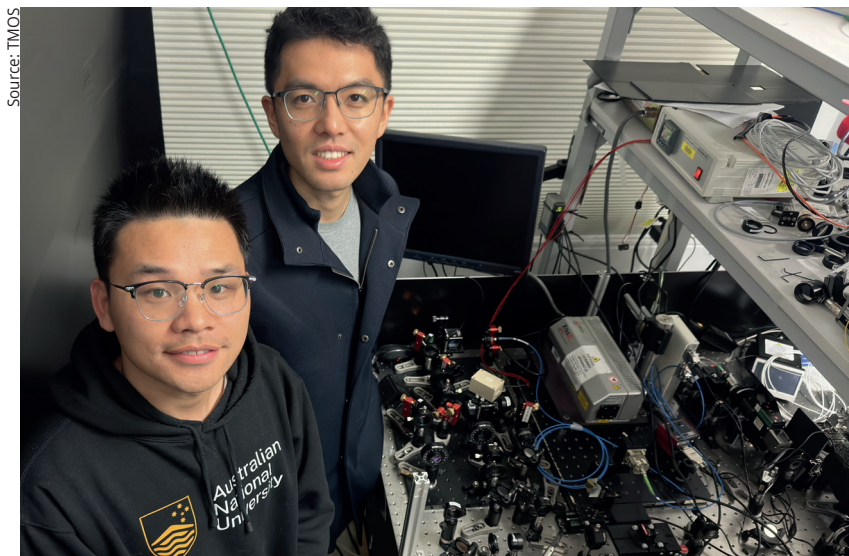
Your daily quantum of photonics news

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Quantum photonics with nanostructured metasurfaces

New approach shows a huge potential to facilitate the miniaturization of quantum photonic devices



Jihua Zhang and Jinyong Ma use metasurfaces for quantum photonics

An increasing number of emerging quantum applications operate using optical technologies. Many of these require photons that are identical, indistinguishable. When the photons are not identical, it can lead to errors in the data and quantum technologies become less reliable. Currently, quantum photon sources are regularly taken offline to be tested and adjusted using an interferometer. This requires com-

paring photons multiple times using different configurations, a process that is time consuming and requires relatively bulky equipment that can accommodate the various physical arrangements.

Real-time analysis of photon indistinguishability that can be conducted within a device while it operates could improve the precision of quantum technologies. Researchers at the ARC Centre of Excellence for Transforma-

tive Meta-Optical Systems TMOS have designed and demonstrated a new device that uses an ultrathin metasurface to do all the necessary measurements in a single pass.

One essential advantage is that this multiport interferometer is single-element, which not only reduces the size but also make it ultrastable when compared with previous multiport interferometers in the free-space optical setup. The use of meta-optics further decreases the size, weight and power of the device, as well as the cost of production. Flat optics, as meta-optics has become known, is key to miniaturizing optical systems, which will in turn lead to the miniaturization of devices we use day to day.

Jinyong Ma says, "After successful simulations, fabrication and a one-off calibration, we were able to successfully characterize the similarity of the photons' spatial mode, polarization and spectra." (Source: ARC / ANU)

J. Zhang et al.: Single-shot characterization of photon indistinguishability with dielectric metasurfaces, *Optica* 11, 753 (2024); DOI: 10.1364/optica.516064

www.tmos.org.au

More precise nanoscopic techniques with quantum sensing

A new technique to enhance superresolution imaging techniques with single-photon sources as probes

Researchers from the University of Portsmouth have unveiled a quantum sensing scheme that achieves the pinnacle of quantum sensitivity in measuring the transverse displacement between two interfering photons. This new technique has the potential to enhance super-resolution imaging techniques that already employ single-photon sources as probes for the localization and tracking of biological samples, such as single-molecule localization microscopy with quantum dots.

Traditionally, achieving ultrahigh precision in nanoscopic techniques has been constrained by the limitations of standard imaging methods, such as the diffraction limit of cameras and highly magnifying objectives. However, this

new quantum sensing scheme circumvents these obstacles, paving the way for unprecedented levels of precision.

At the heart of this innovation lies an interferometric technique that not only achieves unparalleled spatial precision, but also maintains its effectiveness regardless of the overlap between displaced photonic wave packets. The precision of this technique is only marginally reduced when dealing with photons differing in nonspatial degrees of freedom, marking a significant advancement in quantum-enhanced spatial sensitivity.

Vincenzo Tamma, director of the Quantum Science and Technology Hub, said: "These results shed new light on the metrological power of two-photon spatial interference and can pave the way to

new high-precision sensing techniques. Other potential applications for the research could be found in the development of quantum sensing techniques for high-precision refractometry and astrophysical bodies localization, as well as high-precision multiparameter sensing schemes, including 3D quantum localization methods." (Source: U Portsmouth)

D. Triggiani & V. Tamma: Estimation with Ultimate Quantum Precision of the Transverse Displacement between Two Photons via Two-Photon Interference Sampling Measurements, *Phys. Rev. Lett.* 132, 180802 (2024); DOI: 10.1103/PhysRevLett.132.180802

www.port.ac.uk/research/research-groups-and-centres/quantum-science-and-technology-hub

An intrinsically stretchable quantum dot display

A QLED for wearables with record-breaking performance

In the rapidly evolving world of display technologies, the quest for creating intrinsically stretchable displays has been ongoing. A team of South Korean scientists led by Kim Dae-Hyeong of the Center for Nanoparticle Research within the Institute for Basic Science (IBS) has now pioneered a novel approach to stretchable displays, an intrinsically stretchable quantum dot light-emitting diode (QLED).

Traditional displays, constrained by rigid and inflexible components, have struggled to evolve beyond flexible ones. There has been a clear need for novel materials and device designs that can endure significant stretching while maintaining their functionality, which is essential for applications including wearable and adaptable interfacing technologies. The majority of the flexible displays on the market employ organic light-emitting diode (OLED) technology. However, OLED often has drawbacks such as limited brightness and color purity issues. On the other hand, QLED displays offer excellent color reproduction, brightness, and longevity, making them a compelling choice for consumers who prioritize these factors.

However, the intrinsic challenge for developing flexible QLED displays lies in the nature of quantum dots (QDs) themselves; as inorganic nanoparticles, they do not possess inherent stretchability. There have been some attempts to embed QDs within elastic materials to create a light-emitting and elastic composite material. A significant hurdle encountered during this approach was the elastomers' insulating properties, which impede the efficient injection

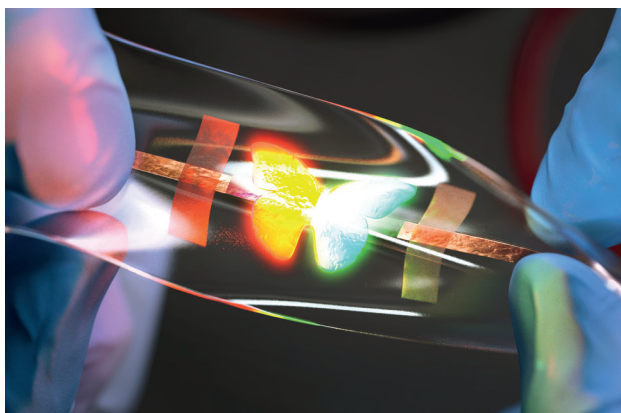
of electrons and holes into the QDs, thereby diminishing the device's electroluminescent efficiency.

Hence the IBS researchers had to come up with innovations to overcome these limitations. They incorporated a third material in the composite to enhance carrier delivery to the QDs. A p-type semiconducting polymer (TFB) was employed to enhance both the stretchability of the device and the efficiency of hole injection. Adding TFB also improved the balance between the electron and hole injections. An intriguing aspect of the ternary nanocomposite film was the distinctive internal structure exhibiting phase separation, where TFB-rich 'islands' are formed at the base and QDs embedded in a matrix lay on top of these islands. This unique structural arrangement minimizes exciton quenching sites and enhances hole injection efficiency, resulting in optimal device performance.

After careful selection and engineering of these materials, the researchers achieved QLEDs with high brightness of 15,170 cd/m², which is the highest among the stretchable LEDs, in addition to a low threshold voltage (3.2 V). The device did not suffer damage even when significant force was applied to stretch the material. Even when stretched up to 1.5 times, there was no significant change in the distance between the quantum dots inside the device. (Source: IBS)

D. C. Kim et al.: Intrinsically stretchable quantum dot light-emitting diodes, *Nat. Electron.*, online 15 April 2024; DOI: 10.1038/s41928-024-01152-w

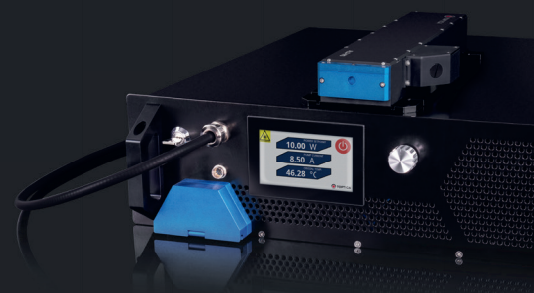
<https://nanomat.ibs.re.kr>



The is-QLED could be stretched to 150 % with consistent device performance

power.

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Shaping the future of photonics and quantum technology in Germany

The future opportunities and challenges of photonics and quantum technology were addressed at the Photonics Germany Future Summit in Berlin on 11 June 2024

Photonics Germany, the alliance of Spectaris and OptecNet Deutschland, invited leading players from business, research and politics to present new technologies and opportunities in photonics and quantum technology. The needs for action were discussed together with 100 participants. A get-together with a BBQ at the Sky Lounge Deck5 the evening before offered an excellent opportunity for networking and establishing new contacts.

In her summit opening keynote, Dr Katrin Kobe, CEO of Bosch Quantum Sensing, highlighted the importance of photonics for various key applications. She also gave some definite recommended actions for the future viability of photonics and quantum technology in Germany.

Dr Thomas Rettich, executive board member of Photonics21, gave an overview of the European research funding of photonics within the framework of the Photonics21 technology platform, and presented some successful projects. He pointed out that participation in the design of the new EU research framework program is possible via Photonics21.

Subsequently, Dr Peter Soldan, head of quantum systems at the VDI Technology Center, dealt with the current and planned funding programs of the Federal Ministry of Education and Research (BMBF) and emphasized that photonics and quantum technologies are equally addressed. He also presented



The participants of the Photonics Germany Future Summit and Industry Meeting 2024

the recommendations for action of the Photonics Germany position paper (in 2022), and explained which topics were taken up by the BMBF.

Michael Kellner, Parliamentary State Secretary at the Federal Ministry for Economic Affairs and Climate Action (BMWK), gave the following words to the participants: "Photonics is an industry that is growing, that is agile, and that is leading the way. Congratulations!" In his speech, he addressed export control, research funding, the recruitment of skilled workers from abroad, and bureaucracy. He explained that there are ongoing intensive efforts by the federal bodies to achieve substantial improvements.

Dr Andreas Ehrhardt, Photonics Germany, presented highlights and perspectives of photonics and quantum technology. He highlighted the current

situation of photonics and the economic framework, and emphasized the urgent need for political action to maintain a leading international position.

Prof Dr Volker Sorger, University of Florida, emphasized the importance of photonics for the US Chips Act and gave insights into activities at the University of Florida. Numerous opportunities for business relationships with German companies can be considered here.

The perspective of the Research Committee of the Bundestag became apparent in the presentation by Dr Holger Becker, Member of the Bundestag. He approached the question "Can Germany innovate?" with examples of strategy papers that take photonics into account as well as with aspects of the current need for action. Lighthouse projects are helpful to increase the visibility of photonics in politics. In passing, he mentioned that only 30 of 735 members of the Bundestag have a STEM degree, which is disadvantageous for the implementation of high-tech topics.

Afterwards, Dr Holger Becker, Dr Katrin Kobe, Prof Dr Karl Leo and Dr Peter Soldan discussed the future viability of the photonics industry in Germany, moderated by Jörg Mayer, managing director of Spectaris. The panel discussion questioned how the photonics industry deals with the numerous challenges, including increasing trade barriers, geopolitical conflicts, a shortage of skilled workers, high tax burdens, energy costs, and social security contributions as well as excessive



Panel discussion (l-r) Dr Katrin Kobe, Dr Peter Soldan, Dr Holger Becker, Prof Dr Karl Leo, Jörg Mayer

bureaucracy, and what it takes to stay successful in Germany and worldwide.

Prof Dr Karl Leo, TU Dresden, presented organic semiconductors on the way from laboratory curiosity to mass production. Dr Michael Overdick, Sick, dedicated his presentation to optical sensor technology and artificial intelligence in automation and logistics. Prof Dr Joachim Ankerhold of Ulm University then gave an insight into the basics, the challenges and the perspectives of

quantum technology. He emphasized the importance of networks consisting of companies, research institutions and other partners to advance new technology together.

Prof Dr Christoph Runde, VDC Fellbach, presented the different technologies and potentials of the Industrial Metaverse for photonics and quantum technology. At the end of the event, Prof Dr Martin Roth, University of Potsdam, explained the innovation potential of

astrophysics, and presented industrial applications based on developments in space travel and astronomy.

The organizers thank the sponsors Fiberware and Zeiss, who made a valuable contribution to the success of the event, as well as OptecBB for their financial support of the networking event at Deck5. They also thank the speakers for their inspiring contributions and all participants for the intensive exchange.

www.photonics-germany.de

EMVA general assembly elects new board of directors

Dr Chris Yates continues another term as president, Dr Kai-Udo Modrich becomes vice president, Arndt Bake remains treasurer

During the general assembly of the European Machine Vision Association (EMVA) which took place on June 13 in Gdansk, Poland, prior to the 22th EMVA Business Conference, the new board of directors consisting of nine members was elected.

For the upcoming three-year term the following board members were re-elected: Arndt Bake – Basler, Dirk Berndt – Fraunhofer Institute for Factory Operation and Automation IFF, Marco Diani – iMage S, Kai-Udo Modrich – Zeiss Inline Inspection & Metrology, Ronald Mueller – Vision Markets, and Chris Yates – Vision Ventures.

In addition, the EMVA welcomes three newly elected members in its board of directors, namely: Petra Thanner – Austrian Institute of Technology (AIT), Benjamin Cocquelin – Tiama, and Maurice van der Aa – Advantech Europe.

During the constituent meeting the new elected board of directors voted for Chris Yates as EMVA president. Kai-Udo Modrich will serve his first term as vice president and Arndt Bake will again be treasurer.

The 23rd EMVA Business Conference takes place from May 22 – 24, 2025 in Rome, Italy.

www.emva.org



L-r: Dr Ronald Mueller, Arndt Bake, Dr Marco Diani, Dr Chris Yates, Maurice van der Aa, Benjamin Cocquelin, Petra Thanner, Dr Dirk Berndt, Dr Kai-Udo Modrich (Source: EMVA)

Successful kickoff of new QBN photonics working group

Quantum Business Network adopted a photonic quantum technologies strategy, elected WG heads Giulia Guarda, Trevor Demille

The new Quantum Business Network Working Group Photonic Quantum Technologies (WG PQT) aims to build a thriving and interconnected ecosystem for growth and development in this cutting-edge field. It aims to foster an environment where collaborations are seamless and practical applications develop rapidly. By connecting research institutions, industry leaders, and government bodies, the working group wants to accelerate advancements and focus on elevating the industry and the global quantum technology market. Through showcasing achievements and facilitating international partnerships, it aspires to shape the future of this technology and drive transformative changes across various sectors.

The gathering elected Giulia Guarda, quantum photonics consultant for QTI srl (Quantum Telecommunications Italy), and Trevor Demille, head of quantum hardware R&D at Quix Quantum, as leaders of the working group.

The working group's mission is to advance the photonic quantum technology industry by building connecting experts, companies, and research institutions. It will promote collaborations through workshops, meetings, and consortia, inspiring investment and interest by showcasing innovative research and commercial products.

It addresses industry challenges, develops practical use cases, and defines technology compatibility and integra-



Giulia Guarda



Trevor Demille

tion standards. The group maintains a directory of key players and provides a platform for knowledge exchange and resource sharing, ultimately striving to create a collaborative and innovative ecosystem for photonic quantum technology.

<https://qbn.world>

Source all images: QBN

Recap of the EPIC Technology Meetings in spring

Discussed topics: fiber optics and integrated photonics



Group picture of the attendees in Lannion (France), a unique photonics hub (Source: EPIC)

The dramatic scenery of high cliffs overlooking the sea and expansive beaches at low tide is home to the French Optical Pole, where we held the EPIC Technology Meeting on Specialty Optical Fibers: New Designs and Novel Applications. We met at the facilities of Photonics Bretagne in Lannion, where we heard great insights from keynote speakers like SNCF Réseau, Exail and Orange Labs. During our visit, we witnessed the strong tradition of research

and development in telecommunications and saw how several photonic companies emerged in this environment to develop various laser sources, sensors, lidar solutions, and optical fibers.

Berlin is the place to be in spring, and the 92 participants at the EPIC Meeting on Integrated Photonics at Fraunhofer IZM know it well. The sessions of this two-day event covered topics such as integrated photonics in volume, advanced packaging, and reli-

ability and testing. The keynote presentations featured remarkable insights from Nvidia, Fraunhofer IZM, Phix Photonics Assembly, and Ficotec. Leaders in the field shared their latest advancements and innovative methods, setting the stage for a future where integrated photonics will revolutionize sectors such as telecom, datacom, healthcare, automotive, and sensing.

<https://epic-photonics.com>



Group picture of all the attendees at the Fraunhofer IZM facilities in Berlin, Germany (Source: EPIC)

Save the date for EPIC upcoming events:

- 2 – 6 September 2024
EPIC Members Delegation to Taipei, Taipei, Taiwan
- 11 September 2024
EPIC Techwatch at CIOE Shenzhen, China
- 16 September 2024
EPIC Online Technology Meeting on Hybrid Photonics Integrated Circuits, online
- 17 September 2024
EPIC Technology Meeting on Photonics for NewSpace – Optical Communication during the ESA Industry Days, Noordwijk, The Netherlands
- 18 – 19 September 2024
EPIC Technology Meeting on Photonics for Miniaturized Optics: from components to use-cases at

- Sony DADC, Salzburg, Austria
- 23 – 26 EPIC Activities at ECOC VIP Networking Reception Career Booth · Frankfurt, Germany
- 25 – 26 September 2024
EPIC Technology Meeting on Laser Micromachining: New Developments and Applications at Light Conversion Vilnius, Lithuania
- 26 September 2024
EPIC VIP Breakfast and Techwatch at W3+Fair, Jena, Germany
- 7 October 2024
EPIC Online Technology Meeting on Neuromorphic Cameras online
- 8 October 2024
EPIC Technology Meeting on Photonics for Quantum Technology at

Quantum Effects, Stuttgart, Germany

- 21 October 2024
Day of Photonics
- 21 October 2024
EPIC Online Technology Meeting on Industrial Laser Processes for Automotive and Electro-Mobility, online
- 28 October 2024
EPIC Online Technology Meeting on Photonics Technologies for Advanced Light Sources, online

For the list of all events, visit:



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

“Be prepared to be humbled, to listen, and learn a lot”

EPIC interview with Thorsten Mayer, CEO at Vanguard Automation

Jérémy Picot-Clément



Source all images: Vanguard Automation

The head of the German producer of photonics packaging and integration technology shares his insights with EPIC's photonics technologies program manager.

How did you become the CEO of Vanguard Automation?

In my first job post-graduation in aerospace engineering at a German software and engineering firm, I quickly discovered my interest in marketing, sales, and general management. I fortunately had great mentors and supporters back then who, in the context of a mid-size company with a flat hierarchy, allowed me to gradually take on more responsibility, to fail, learn, and grow. These valuable early lessons helped me finding my path when NI – National Instruments – acquired us in 1999.

NI – now part of Emerson – was a large US public company and market leader for software defined test, measurement, and automation systems. Still led by its founders at the time, the company has been developed on the basis

of a strong vision and unshakable core values. Over the next 20+ years I had the opportunity to grow in a range of regional and global senior leadership positions in sales, marketing, and operations, contributing to the transformation of a 300-million dollar company into a 1.5-billion dollar globally-recognized market leader and a ‘best place to work’. This was a great hands-on learning experience as it gave me the opportunity to grow professionally and personally and various dimensions. I had the opportunity to live and work in four countries and ended up living in Austin, Texas, where I also volunteered in the start-up community.

Then, literally by accident – or call it destiny – I got connected to the founders of Ficontec and Vanguard Photonics, who had jointly founded Vanguard

Automation and happened to be looking for an executive leader. While the thought of moving overseas with my wife and three children for a startup seemed ambitious and risky at best, I was sold after I had learned more about the technology and – more importantly – after I had met the people behind the technology and Vanguard Automation. I joined the team in November 2020 and, over a period of one year, I transitioned into the role of CEO.

What motivated you to move from a high-powered job with a multinational to a start-up with a completely different technology?

After NI's first CEO transition, I took inventory as well. I have enjoyed the roles where I have had the opportunity to build and grow the business while



Machinery in the clean room at the Karlsruhe site

working with multiple functions of the organization. Contributing to building a centralized central-eastern European organization from scratch, and later leading and growing a region of nine countries was an extremely developmental period for me which has left a deep and profound impression. In addition, I enjoyed being part of an angel investment organization where I volunteered my time in due diligence, deal making and advising. I developed a genuine appreciation for the courage of start-up founders and their impact on global innovation overall. While the proposition of turning my life upside-down for a start-up seemed crazy at first, it seems to have been simply the right thing to do – professionally and personally.

I have been humbled by the technology, its potential, and relevance in the marketplace. Moreover, it was very encouraging to see what had already been achieved by the extremely talented people at Vanguard Automation. Advancing the use of photonic integrated circuits and the scale at which photonic systems can be deployed will be paramount to continuing the path of innovation we are on as a people,

whether it is communications, sensing, machine learning, or augmented reality.

Vanguard Automation is in a clear position to contribute significantly to how easily new photonic systems can be developed and manufactured in the future.

What were your main challenges when you became CEO at Vanguard?

Firstly, moving into a new industry meant I had to be prepared to be humbled, to listen, and learn a lot. I do firmly believe that it is essential for the CEO of a high-tech firm – small or large – to be able to understand the technology, value proposition and markets at a level that allows her/him to present, discuss, and challenge – internally and externally – without having to be a deep technical expert. So since the beginning I have joined many customer meetings just listening and learning, as well as internal team meetings, and quizzed the staff on countless topics.

Secondly, I had to adjust to new market dynamics. While NI had grown tremendously for a while, the test and measurement industry is well developed with overall slow growth rates. The photonics world is so much more

dynamic with innovation emerging as we speak. The industry is also inherently global, such that we not only compete on a technological level, but also against geographies with much better access to innovation and growth capital. Time to market and the ability to serve large global customers do matter!

Thirdly, I entered the role with the utmost respect for those who had developed the technology and had built the company thus far, both the employees as well as the shareholders. At the same time, I brought a wealth of experience with me, and inevitably not only have had different views on certain topics, but sometimes also strong opinions. Judging when to push it and when to trust in others having more expertise in the field has been an ‘interesting’ balance.

How has the company developed?

Let us take a step back and talk about what we do briefly; Vanguard Automation has developed industrial-grade process technology consisting of machines, software, and materials for automated multichip assembly based on 3D-nanoprint technology. More specifically, these processes are designed to create low-loss photonic connections between passive and active optical components, leveraging a unique IP portfolio for photonic wire bonding and facet-attached micro-optics. In addition, we provide a range of services including training, standard and development support, and maintenance services around our product offering.

2023 marked our fourth consecutive profitable fiscal year, and we are approaching a workforce of thirty. We meanwhile work with two contract manufacturers in the EU that perform the mechanical and electrical assembly of our machines. We have deployed

Company

Vanguard Automation

Headquartered in Karlsruhe, Germany, Vanguard Automation (VA) develops technology and products including machines, software, materials and processes for creating low-loss photonic interconnects between passive and active optical components. These so-called photonic interconnects are fabricated using VA's globally unique IP portfolio for photonic wire bonding and facet-attached microlenses. Building on nanoprint technology, VA's solutions enable high packaging density, increased design flexibility and fabrication throughput. In April 2024, VA joined the Swedish high-tech group Mycronic AB, a publicly-traded global leader in electronics manufacturing solutions.

www.vanguard-automation.com

over thirty machines, the larger portion of which is being installed in North America and Asia. Our customer base consists of larger commercial accounts, service providers, academia, and technology centers.

What are the factors of your success?

There are certainly several things that have to come together. Not questioning the uniqueness and relevance of the technology here, the following are the factors that I believe have been critical.

Number one was a fast transition from the initial intellectual property developed at Karlsruhe Institute of Technology under the leadership of professor Christian Koos to an industry-grade product. This enabled the company to engage in real industry opportunities early on, validating the value proposition and getting valuable feedback to focus its efforts.

A second related factor of the fast transition to an industrial grade product allowed us to start selling product swiftly. This helped to validate the business model and pushed us to operate like a 'real company' early on. We transitioned quickly from being funded by early investment and funded research projects to being primarily funded by product sales.

Both of the above were mainly possible by teaming up with a joint-venture partner – ELAS Technologies Investment – who brought twenty years of experience in industrial machine building and a global network of business contacts to the table.

Thirdly, and I believe the most critical factor, were the people. Since the second half of 2021, with the exception of Dr Philipp Dietrich, the company has been employee-led. I definitely have to give a huge shout-out to our leadership team members, in particular those who have been there from the get-go: Dr Matthias Lauermann, head of R&D and manufacturing, who has been the driving force behind the development of the machines and processes; Dr Sebastian Skacel, head of technical operations including applications, support and services, who very early on took charge of our customer engagements from initial customer contacts to feasibility/proof of concept, demos, machines acceptance test, training, support and services; and Dr Philipp Dietrich, technology fellow and co-founder of Vanguard Photonics, who has done a fantastic job on the technology side,

leading our research engagements as well as developing strategic technology partnerships.

How do you see the future?

As you know, very recently we joined the Swedish high-tech group Mycronic. We started the search for a growth partner almost over one year ago. At that time Vanguard Automation had already been operating profitably and we had positioned ourselves within commercial accounts working closely on qualifying the technology for production. I knew that as soon as one overcomes all the technical hurdles, topics such as global footprint, financial strength, and supply chain security will come into the mix. It was clear that we had to prepare to grow more than we had done in the past. Trying to do this organically would have taken too long for an extremely dynamic market with global competition.

Joining Mycronic marks a significant milestone not only for our teams, but also for our partners and customers. It is a reflection of the tremendous work that has been going into bringing 3D-nanoprinting technology to volume production applications, and it rings in the next phase of growth and development on our journey of being a future-proof partner for building photonic devices.

Organizationally, Vanguard Automation remains unchanged and forms a new business unit within the global technologies division, which is run by me and the management team that has helped to build the company. I will remain managing director of Vanguard Automation. Within the Mycronic group I will serve as vice president and general manager on the leadership team of the global technologies division.



The technical leadership team (l-r): Philipp-Immanuel Dietrich, Matthias Lauermann, Thorsten Mayer, Sebastian Skacel

What is your advice for the next generation of entrepreneurs?

Firstly, building a strong team early on is crucial – not only who you bring into the company but also who you choose as advisors and mentors. In this context, do not be shy about hiring people who in some areas are 'better' and/or more experienced than you are.

Secondly, building a minimum viable product to a validated value proposition and business model with your target audience is paramount for progress into the right direction. In the process you will learn what is really needed to complete your technology and build a competitive solution, both technically and also as far as your customer engagement process is concerned.

Thirdly, do not underestimate the resources you will need to get from a first prototype to an industry-grade and qualified solution. Time does matter in a highly competitive and global marketplace. Bringing these resources together will be paramount, and will take a considerable effort as well.

Author

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



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Innovations and challenges in modern optical design

Revolutionizing the field of optical design to enable faster and more accurate optimization of complex optical systems

Jérémy Picot-Clémente



Source: Dispelix

Optical designers are constantly pushing the boundaries of technology, developing new materials, techniques, and software tools to improve the design and optimization of optical systems – crucial for continued growth and innovation in areas such as virtual reality, autonomous vehicles, and quantum technologies.

Optical design and simulation involve the use of computational tools and techniques to model, analyze, and optimize optical systems. These systems can include lenses, mirrors, waveguides, lasers, and other photonic components. The goal is to achieve the desired optical performance while minimizing aberrations, losses, and other inefficiencies. These advancements are crucial for innovations in fields such as telecommunications, healthcare, and entertainment.

There are six key components of modern-day optical design:

1. **Ray tracing:** analyzing how light interacts with different components in optical systems
2. **Wave optics:** studying diffraction, interference, and polarization effects

3. **Optimization algorithms:** fine-tuning design parameters to achieve optimal performance
4. **Multiphysics simulation:** combining optical, thermal, and mechanical analyses for holistic design
5. **3D modeling:** enabling detailed visualization and manipulation of complex optical systems
6. **High-performance computing (HPC):** facilitating the simulation of large-scale photonic systems with high precision.

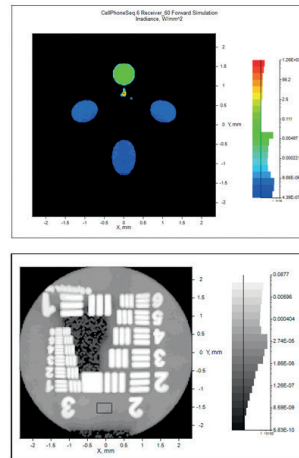
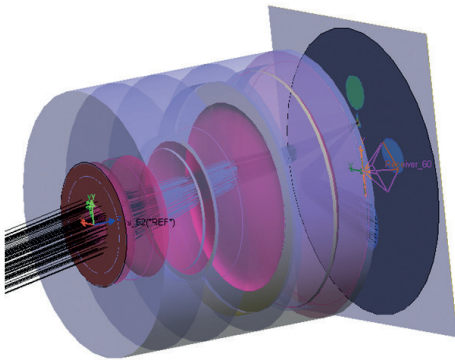
Logic synthesis and PICs

Founded in 1986 and headquartered in California, **Synopsys** supplies tools for logic synthesis and the physical design of integrated circuits, simulators for

▲ The Dispelix Selvā – a near-eye waveguide combiner for eyeglass-form XR glasses that displays full color images while simultaneously allowing users to read small font-size texts and view photos and videos.

development, and debugging environments that assist in the design of the logic for chips and computer systems.

In the early 2000s, optics began to evolve into more complex systems, especially in consumer applications, and the design of these new optical systems needed a paradigm shift toward comprehensive simulation platforms. Accordingly, Synopsys made a number of acquisitions between 2010 and 2014, and they now have a comprehensive



Cell phone pancake lens modeled in LightTools with diffraction distribution simulated in RSoft DiffractMOD RCWA (Source: Synopsys)

portfolio to design, optimize, and test optical systems for consumer, advanced driver-assistance, AR/VR/MR, and aerospace and defense applications.

The design component of their optical platform comprises CODE V, LightTools, RSOF and the LucidShape family, together with SmartStart Libraries and instruments (REFLET/MiniDiff). Because the systems are becoming more complex, a high level of computing support is also required (either multithreads, distributed computing or GPU-enabled), together with engineering support.

Communication systems & PICs

Based in Ontario, Canada, **Optiwave** supply tools for optical simulations and instrumentation. At the system level, they have the Optisystem, which comprises various kinds of visualizers and post processing capability for more than 580 components and can deal with various communication systems, including coherent and non-coherent, quantum, and free-space optics.

At the circuit level, they have OptiSPICE for the design and simulation of photonic integrated circuits with two versions available: a standalone for PIC design using a schematic, and a plug-in version that can connect with other EDA tools.

They also have photonic device level simulators to see how light scatters from the device. There are also grating, fiber and other modes that assist with different kinds of sensing applications. Finally, they have OptiInstruments that communicate with instruments and

automate their operation using remote control scripts to enable system building from the ground up.

Diffraction waveguides for AR applications

Dispelix, a Finnish company founded in 2015, develop, design, and manufacture cutting-edge diffractive waveguides for extended reality (XR) devices that seamlessly combine the virtual and the real.

Their waveguides work on the principle of surface relief gratings whereby one grating couples light from the light engine, which is guided inside the waveguide through an expander and finally to the eyes via an out-coupler.

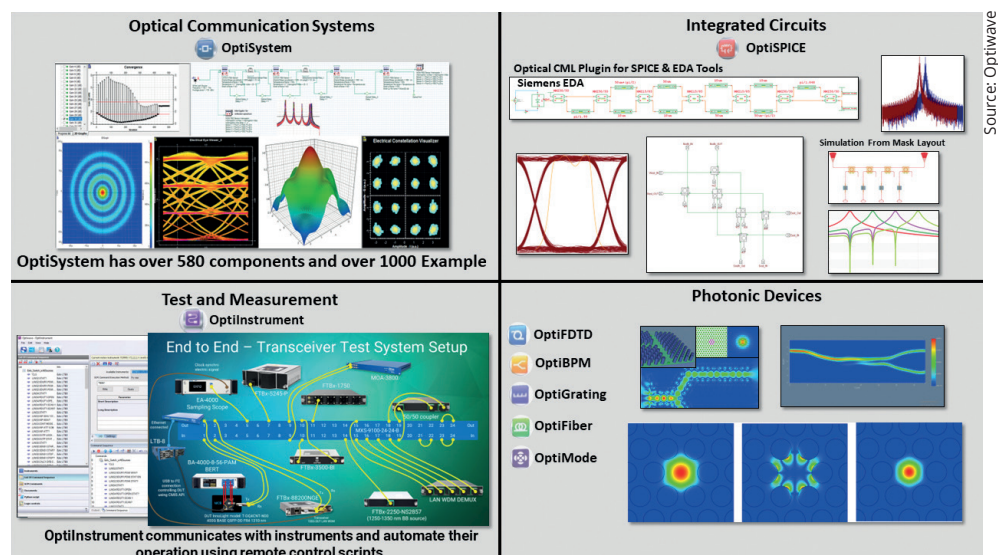
The main design challenges stem from the fact that gratings are on a nanometer scale, but the waveguides are on a centimeter scale, so the challenge is how to combine simulation of nanoscale diffractive gratings with macroscale waveguide dimensions.

To address these challenges, Dispelix, have developed proprietary simulation software (Waveguide Studio)

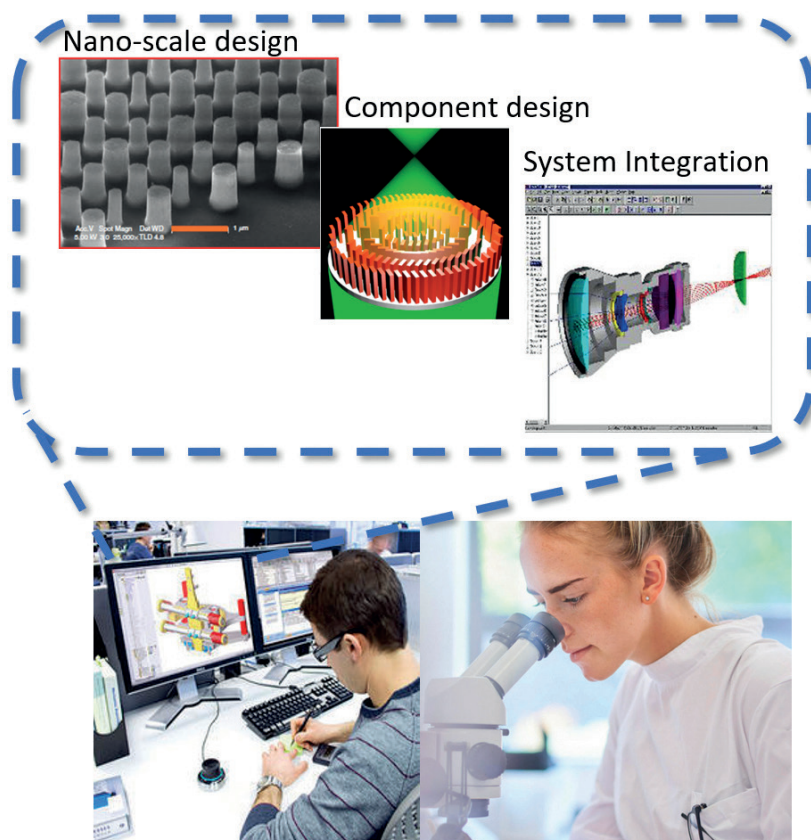
with a graphical user interface that merges conventional algorithms and AI features, and has a design capability for both LED and laser waveguide combiners. With this software, they can take into account linear and double periodic gratings with all possible propagation directions, together with field propagation with polarization and phase including interference and coherence effects. Additionally, they can optimize the modulation transfer function, include tolerancing into the simulation, and the system is compatible with high performing computing clusters.

Wavefront modulators

Phaseform, a spin-off from the Laboratory for Micro-optics in the Department of Microsystems Engineering (Imtek) of the University of Freiburg in Germany, have developed a novel optofluidic microsystem technology called deformable phase plate (DPP), which enables transmissive, high spatial-frequency, continuous-sheet wavefront modulators with a compact footprint.



► Software Integration between the different Optiwave products



Planopsim supplies R&D tools to unlock the maximum benefit of flat and meta optics in a user-friendly way (Source: Planopsim)

Its unique features combine the advantages of deformable mirrors and transmissive liquid crystal spatial light modulators in a compact form, paving the way for a new class of ultracompact, high-efficiency, transparent wavefront modulators. They have developed a digital model of DPP representing its empirical properties that can be inserted into OptiStudio just as you would with a lens DLL.

The first commercial product to incorporate this technology is the Phaseform Delta 7 wavefront modulator. Designed mainly for optics designers for applications ranging from life science, microscopy, and material science, to semiconductors, 3D nano printing and AR/VR/MR, this device

is a continuous-sheet, refractive, opto-fluidic wavefront modulator that features a 63-electrode deformable phase plate capable of replicating up to the 7th radial order of Zernike modes.

Planar optics and metasurfaces

Based in Belgium, **Planopsim** offer easy-to-use design software for planar optics and metasurfaces in an all-in-one design workflow, as well as design services that include manufacturing prototypes and custom training.

The software is dedicated metasurface in its user interface and design workflow, and has several advantages over conventional tools. These include high speed (18× faster than FDTD) and 4000× larger areas, ray tracing scripting

to enable export to manufacturing, full metasurface workflow, and dedicated metasurface support.

The workflow in their software goes in an iterative cycle that starts with system modelling to find specifications for the nano structures and components. The next stage is to build a library of nano structures. This is followed by component design to produce the necessary wave fronts over different polarizations, different angles of incidence and different wavelengths, which are then analyzed for their optical behavior. Local periodic approximations are then verified by an ODA tool, and all the data is fed back into the ray tracing software.

The next step is to optimize the metalens, which is done in the physical optics regime and involves analyzing the wave fronts provided by the user to check how the actual point spread function changes with different angles of incidence or different propagation. This can be done on lenses of up to 6 mm in diameter, and the data are output directly to GD files for manufacturing.

Modelling silicon photonics

Founded in Oxford, UK in 1992, **Photon Design** are involved in optical waveguides and optical lasers. The company has pioneered many innovative techniques to model silicon photonics, e.g., the invention of the first practical eigenmode expansion tool (EME-FIM-MPROP). This tool provided the first practical solution for the modelling of large silicon photonic devices and it now provides a complete suite of tools for a large range of passive components.

Photon Design has also provided reliable solutions for active device design such as in gallium arsenide and indium phosphide and laser simulators (PicWave, Harold) that are now used by many of the leading laser diode manufacturers around the world. These models, which are some of the most sophisticated active photonic circuit simulators available in the market, include most of the physical processes in a typical laser diode or active PICs like quantum well effects, gain saturation, thermal and electrical diffusion and reliability modelling.

Engineering simulation software

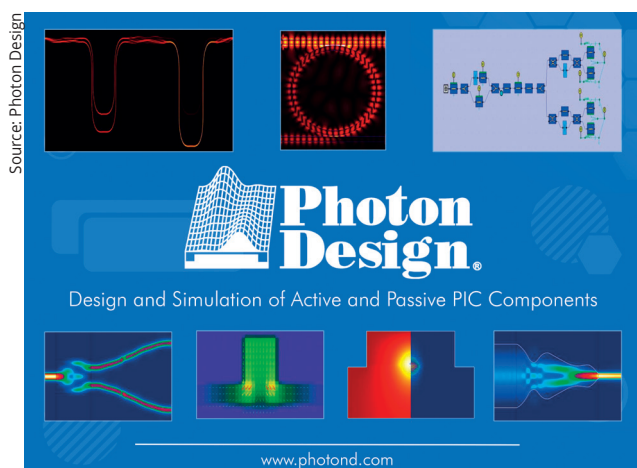
Headquartered in Pennsylvania, USA, **Ansys** develops and markets CAE/multiphysics engineering simulation

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.

www.epic-assoc.com



Design and simulation of active and passive PIC components



Ansys' optics portfolio

software for product design, testing and operation.

Ansys' optics portfolio consists of three software solutions. The first, Lumerical, is for the design engineering of photonic components such as waveguides, sensors, emitters, meta-surfaces / metalenses, and AR coatings that are modelled the nanoscopic / chip level. The second, Zemax, is for the design engineering of optical components such as lenses and mirrors and optical sub-assemblies used in high-precision imaging systems covering analysis, optimization, and tolerancing (i.e. design for manufacture). The third is called Speos and is for design engineering at the system level, with the ability to integrate both photonic and optical components and subassemblies into a full 3D environment that supports physics-based human vision rendering.

Although these software tools can be used independently, they also support seamless data exchange workflows from photonic design to optical design to system design, as well as direct integrations with other multiphysics software solutions (such as electrical, mechanical, structural, and thermal simulation tools). Using all three tools together therefore enables the multiscale, multiphysics design engineering required to develop modern optical products.

Modelling optical fabrication chains

Founded 2018 and based in St Gallen, Switzerland, PanDao have developed a software tool that can be used by optics designers to check for manufacturability during the design stage and to optimize designs for the smallest fabrication costs.

In the case of lens manufacture, for example, the designer simply inputs the

lens data and tolerances as stated from optics design software together with commercial details of the production order (e.g. the number of lenses to be produced). The tool then generates a list of essential optical fabrication techniques to be applied, the optimum fabrication chain, and costs in respect of fabrication, centering, testing, and coating. As an example, Table 1 below shows the optimal design for the lowest fabrication cost in relation to the asphericity of a 220 mm lens.

In the same way, it is possible to determine how a change in material will affect costs. Table 2 below shows the costs of using low-refractive index material N-BK7 compared with the use of high-refractive index material N-SF57 – glass types used for aspherical lens surfaces. Both do the same job, with a Strehl number of 0.8, and although N-SF57 material costs more, the overall cost of N-SF57 is less.

This type of information is hard to determine during the design stage but it can be spotted early on with PanDao's software, making the final product cheaper and saving a lot of development time.

The future of optical design

Improvements in computational power and algorithms, the integration of artificial intelligence (AI) and advanced materials are revolutionizing the optimization of individual components and the development of novel design methodologies, multiobjective optimization, multiscale and hybrid systems, and end-to-end optimization.

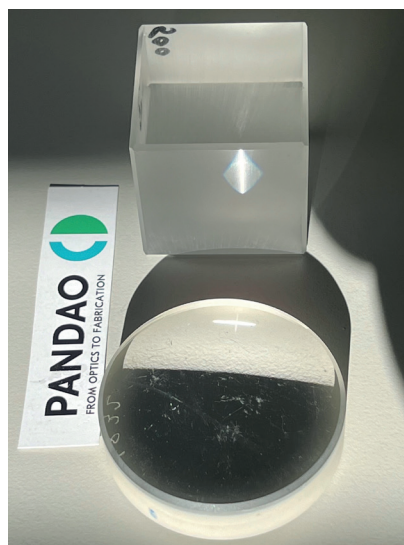
Significant advancements have been made through innovative design approaches in multiscale and hybrid systems. For instance, new design methods for 2D lidar systems have led

to substantial signal gains by employing advanced optical components and novel integration techniques. These redesigns focus on optimizing emitter planes and imaging systems to enhance overall performance.

Collaborations between technology companies and academic institutions are also driving progress in artificial intelligence and novel design methodologies. By shifting from single designs to exploring solution landscapes, the application of AI is expected to automate processes and generate a larger variety of system variants. This necessitates the development of tools that can handle multiple systems simultaneously. A notable example is a recent review article by NTU Singapore and Zeiss that discusses the integration of artificial intelligence in optical lens design, highlighting the transformative potential of AI in this field.

Furthermore, novel methods are emerging in classical areas of optical design. Recent research on principal component analysis (PCA) for color correction presents a fresh perspective on dispersion. This approach, which involves analyzing refractive index spaces, offers a model-free method for color analysis and correction, demonstrating the potential of advanced statistical techniques to improve traditional optical designs.

Looking forward, the future landscape of system performance optimization envisions tools operating within an open environment. This requires unified parametric, optimizable system descriptions that can integrate seamlessly with different modules or tools. Standardized models and data interfaces will be essential for the smooth transfer of data between systems. Additionally, all generated informa-



The PanDao software tool optimizes the producibility of optical systems (Source: PanDao)

tion should be differentiable to build compound merit/loss functions across modules. The need for an open optimization interface, a single visualization environment, and multisystem capability will also be crucial, along with an open environment supporting both proprietary and third party modules.

Future challenges

The future of optical design is set to revolutionize numerous many industries, including telecommunications, healthcare, entertainment, and autonomous systems. As optical systems become increasingly complex and integrated, the demand for advanced materials, innovative design techniques, and powerful simulation tools will grow. Emerging technologies such as metaoptics, quantum photonics, and adaptive optics promise to enhance performance, reduce size, and lower the cost of optical devices. However, these advancements bring significant challenges. One primary obstacle is the need for more sophisticated computational models and high-performance computing resources to accurately simulate and optimize intricate optical systems. Additionally, the integration of diverse optical components requires meticulous design and compatibility checks to ensure seamless functionality. Interdisciplinary collaboration is essential to address the multifaceted nature of optical systems, incorporat-

Table 1: Optimal design for the lowest fabrication cost in relation to the asphericity of a 220 mm lens

12 μm asphericity		8 μm asphericity	
Fabrication chain	Fabrication cost [€]	Fabrication chain	Fabrication cost [€]
CNC sub aperture rough grinding	8.00	Curve generator rough grinding	1.29
CNC sub aperture grinding	27.45	Curve generator grinding	1.86
CCP bonnet	109.92	CNC full aperture	2.06
		CNC sub aperture grinding	19.73
		CCP bonnet	109.92
Total cost	145.38	Total cost	134.85

Table 2: Effects of a change of aspherical lens surface glass type on costs

Costs	Strehl no: 0.8	Strehl no: 0.8
	Low RI material N-BK7	High RI material N-SF57
Strehl fabrication cost [€]	29.3	24.7
Material cost [€]	0.4	2.5
Total cost [€]	29.7	27.2

ing insights from physics, materials science, and engineering.

Artificial intelligence is poised to play a transformative role in the future of optical design. AI-driven algorithms can significantly expedite the design process by automating complex calculations and optimizations, enabling designers to explore a broader range of design options more efficiently. Machine learning models can analyze vast amounts of data from previous designs and simulations to predict optimal configurations and identify potential issues early in the design phase. In a near future, AI will facilitate the creation of more adaptive and responsive optical systems, capable of real-time adjustments based on environmental conditions or user requirements. As AI technology continues to advance, its integration into optical design will not

only help overcome current challenges but also unlock new potential, driving innovation and expanding the capabilities of optical systems across various sectors. As these advancements unfold and challenges are met, the future of optical design will continue to push boundaries, shaping innovations that seamlessly integrate into and enhance our everyday lives.

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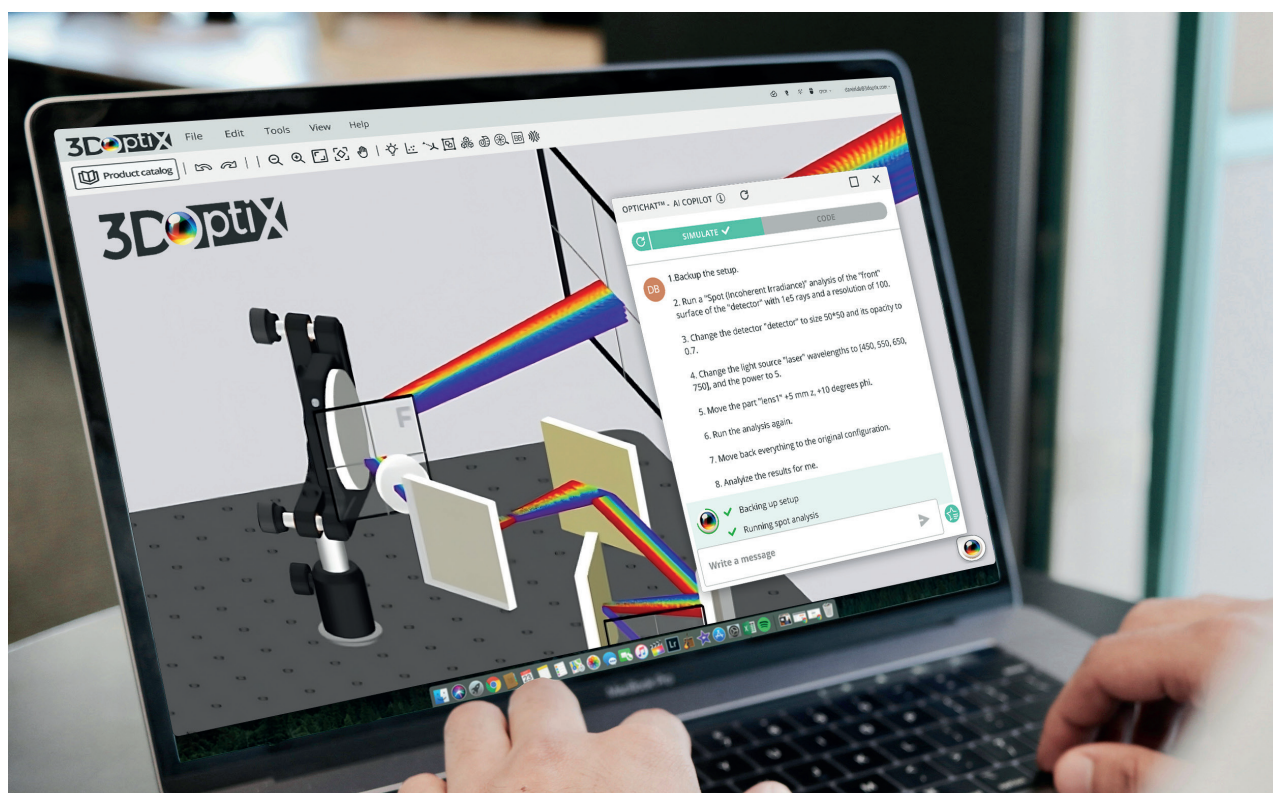


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Creating advanced photonics AI assistants

The first optical design copilot based on a novel dynamic agent approach

Erez Tepper & Haim Suchowski



Source all images: 3DOptix

The AI assistants that have emerged in the past couple of years open up new domains of knowledge, allowing us to be educated and guided in many new and versatile domains. However, for domain experts such as optical designers, scientists, and photonics engineers, they often have limitations in their information accuracy and scope. 3DOptix has developed a dynamic approach to overcome these limitations that enables the creation of a proficient optical design copilot. This copilot assists experts in every step of the design process, including conducting precise calculations, searching for components, and simulating actions.

Optical design, a critical aspect of many scientific and technological applications, presents a wide variety of complex challenges, a mix of mathematical calculations, physical constraints, the search for suitable optical elements, and the execution of simulations – all of which require a high level of expertise and precision. The idea of leveraging artificial intelligence (AI) assistants to aid in these tasks has gained traction over the past couple of years. While its

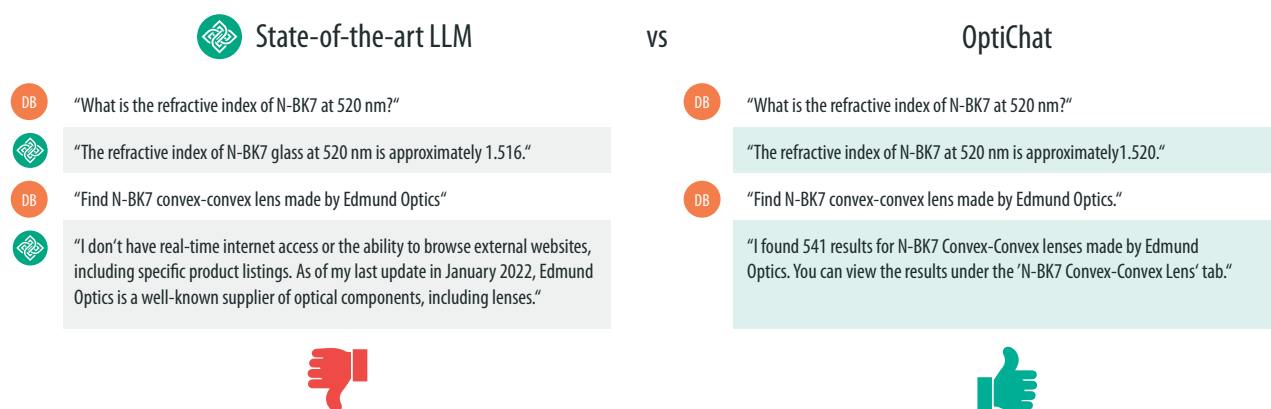
potential has already shown success in a plethora of applications, in the optical design arena it has largely remained untapped due to limitations in existing models.

The makers of 3DOptix, the advanced cloud-based optical simulation software, embarked on a mission to develop OptiChat, the first AI assistant designed to overcome the limitations of traditional AI models for optical design. In this article, we dive into the challenges of

developing AI assistants in optics, present the dynamic agent framework, and show how OptiChat promises to transform optical design.

Large language models

Large language models (LLMs) are a type of artificial intelligence model that is capable of understanding and generating human language. They are trained on vast amounts of text data, which enables them to perform a wide range of



▲ **Fig 1** Comparison of a current state-of-the-art LLM to the OptiChat model in a simple calculation and search task. AI assistant inaccurate response, demonstrating hallucinations and an inability to perform the search (left). OptiChat accurate response (right).

natural language processing tasks. LLMs can leverage numerous deep learning architectures, the most significant ones being variations of the transformer architecture suggested in Ref. [2]. The most famous transformer model is the well-known ChatGPT, which was released by OpenAI in November 2022, but it is not the only one. In the time since then, many models and tools built on them are flourishing in every industry. Almost immediately, these tools have gained immense popularity, transforming how we work, collaborate, and interact with technology.

One significant constraint of LLMs is the limitation imposed by the context window size. The context window refers to the number of tokens – the base units of textual information – that are considered when generating responses. A larger context window allows the model to capture more information from the input, enhancing contextual understanding. However, if the interaction exceeds the context window, the model loses access to the earliest parts of the

conversation, impacting its consistency in handling long conversations or complex tasks.

Additionally, LLMs face challenges in performing accurate mathematical calculations. As these models are primarily designed for language generation, they may struggle with mathematical problem-solving. LLMs often rely on pattern matching based on statistical patterns learned from their training data. The focus on language generation, coupled with the need for precise solutions in mathematics, poses difficulties for these models. It is important to understand that LLMs do not 'perform' mathematical calculations in the conventional sense but rather match patterns, which leads to incorrect results more often than not.

The inability to perform accurate mathematical calculations is one side of a broader noteworthy aspect that is the phenomena of 'hallucinations' in LLMs. Hallucinations occur when the model generates text that is incorrect, nonsensical, or not grounded in reality, while confidently presenting it as true. This can be attributed to the model's limited contextual understanding, reliance on statistical patterns from training data, and data compression during training. These limitations are shown in Fig 1a.

In order to understand these limitations better, let us consider the use-case of finding a lens with an on-demand effective focal length (EFL) at an on-demand wavelength. Given the right instructions and contextual information, a probable outcome is that the model will pretend to calculate the correct lens measurements, and then pretend to find a lens that complies with those measurements or inform the user that they do not have access to the database, all without actually

calculating or knowing that this lens actually exists.

With these goals in mind, 3DOptix developed the dynamic agent approach that allowed the development of OptiChat, and an accurate LLM assistant, specialized for optics. Unlike other AI assistants, OptiChat is capable of assisting with many phases of optical design: performing accurate calculations, searching for optical components with extremely high fidelity outcomes, executing actions in the simulation engine, as well as choosing and chaining the right actions. We start by describing the fundamental concept of the agents that OptiChat is built upon.

LLM agents

An agent can be described as a system that can use an LLM to reason through a problem, create a plan to solve the problem and execute the plan with the help of a set of tools. The description of the available tools and the instructions to use them are in the context of the model. It allows the model to decide which tools to use and when to assist the user better. The model 'activates' them by outputting text in the predefined structure. Then, the tool with the chosen parameters is called, and the response is injected into the model. The most common examples of tools leveraged by LLMs are web search and code execution.

These agents are essentially systems that transform natural language into chains of actions, and the possibilities are endless. Every action we can implement in code and define properly in natural language can be a building block of a conversational agent that assists us in doing that task, especially when you consider action chaining, where the agent executes several actions in a chain or in parallel. Proper utili-

Company

3DOptix

3DOptix is the leading cloud-based design and simulation platform for photonics. 3DOptix' innovative, native, state-of-the-art GPU engine accelerates photonics computations, and offers high-end ray tracing and physical-based simulations. Full integration of 3DOptix with CAD tools provides the most straightforward workflow in the industry to test any virtual optical prototype. Its intuitive user interface and rich analysis portal make it extremely easy to verify the optical accuracy of any design. Founded in 2017, 3DOptix Ltd is a spin-off company from the Femto-Nano Laboratory at Tel Aviv University and is headquartered in Rehovot, Israel.

www.3doptix.com

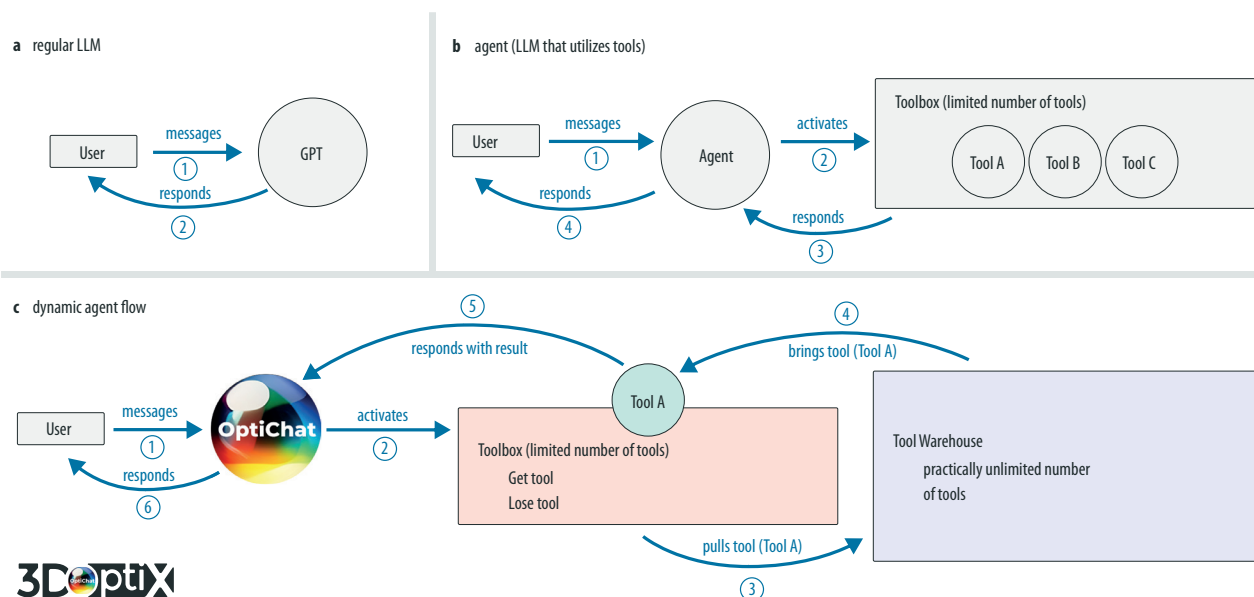


Fig 2 Architectures of different LLM assistants: (a) a classic LLM flow where the user sends a message and gets a parametric response that might suffer from LLM limitations; (b) a regular agent flow where the agent has access to a toolbox and can activate tools based on the conversation with the user; (c) a dynamic agent flow where a limited set of tools is available to the agent, including the ability to transfer tools from and to the toolbox.

zation of the tools can help to mitigate some of the traditional LLM limitations. For instance, access to calculators can allow the agent to perform actual calculations, and the ability to get information from external sources helps to reduce the hallucination risk. This will allow an agent that was equipped with a tool to calculate lens measurements and search a wide catalog of optical elements to perform the calculation correctly and select the right lens, as part of the ongoing conversation.

In order to create a truly viable assistant, a single calculation and a single database search are helpful, but not enough. Many more capabilities are needed, such as running a simulation engine, changing parts, and accessing multiple types of calculations.

Yet, current agents are limited to proper tool usage. Firstly, every additional tool directly reduces the possible length of the conversation with the user that the model can access, so if the agent has a lot of tools, it has less and less room to engage in a conversation with the user and use these tools. More importantly, the model's overall performance decreases as the context size increases, Ref. [4], with information and instructions in the middle of the context tending to be lost as the context size increases. So not only does every additional tool reduce the length of the conversation with the user, but it also increases the probability of mistakes and misuse of the tools.

One common approach to mitigate this issue is to use retriever-augmented generation (RAG) [2] for the tools. In this approach, a retriever module is leveraged to retrieve the tools with the highest semantic similarity to the user request. The agent then uses these tools according to the conversation. The RAG method of tool retrieval has been proven to be highly effective in enhancing the capabilities of agents. For instance, 'Gorilla' [3] utilizes tool retrieving to allow the model to call a large number of APIs. However, in the case of action chaining where the output of one tool

is used as the input of another, RAG is not a sufficient method. Often, the tools that are required in the middle phases of the operation are not semantically close.

The dynamic agent framework

In the quest to address the limitations of agents, and to foster the creation of specialized domain expert assistants, 3DOptix has recently introduced the dynamic agent framework. This innovative approach borrows concepts from cognition, specifically the notions of the 'sense of self', 'theory of mind', and 'self-awareness'.

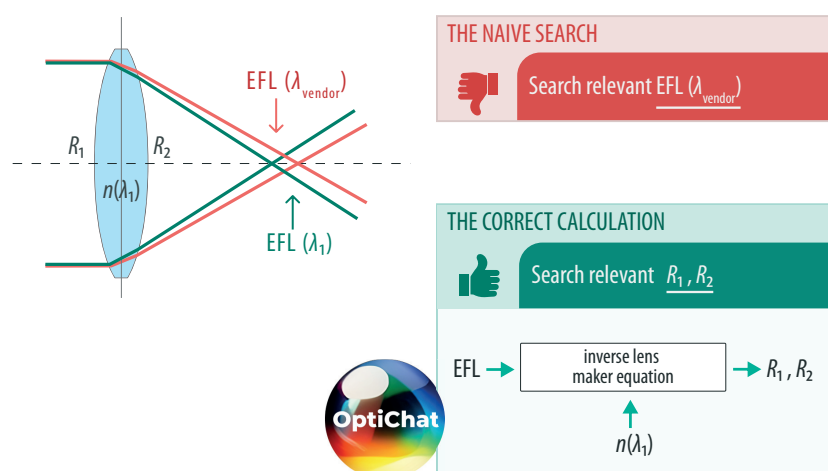


Fig 3 The naive and correct ways of finding a spherical lens with a target EFL at a certain wavelength. While beginners will simply search for lenses with the target EFL and get slightly wrong results because of wavelength differences, experienced designers will calculate the lens measurements that will create the target EFL at their wavelength. OptiChat allows even complete beginners to perform the right chain of actions.

The ‘sense of self’ refers to an individual’s perception of their unique characteristics, encompassing personality traits, abilities, preferences, moral values, and motivational drivers. ‘Theory of mind’ is the capacity to attribute mental states to oneself and others, recognizing that others hold beliefs, desires, intentions, and perspectives that may differ from one’s own. In artificial intelligence, ‘self-awareness’ denotes a machine’s ability to acknowledge its existence and consciousness as a distinct entity within its environment.

Even the most advanced LLMs exhibit only rudimentary levels of these attributes. If at all, they are often comparable to the levels observed in young children. However, we show that we can enhance the capabilities of agents by harnessing these concepts. It is done by allowing the agent to intelligently modify its attributes during an ongoing conversation, depending on the user’s needs.

Within this framework, we introduce the concept of a ‘tool warehouse’. The ‘toolbox’ comprises all the tools the agent can directly access and activate within its context window. Conversely, the ‘tool warehouse’ contains all potential tools that are not within the context window, essentially making it a limitless resource. Fig. 2 describes the different ways to build an LLM assistant. In Fig. 2a, we present the most common chatbot. In that system, the assistant and the user engage in the conversation directly, and all the knowledge the model has is parametric, i.e. comes from the inner parameters of the LLM. Fig. 2b shows the classic agent that has a toolbox to use in order to have a more capable conversation. However, in the classic agent implementation, the number of tools is limited and reduces the linguistic capabilities of the model.

This dynamic approach to tool access empowers the agent to intelligently load and unload tools, based on the current conversation. This facilitates focused operations without the agent being overwhelmed by excessive data while potentially providing access to an immense range of tools, as shown in Fig. 2c. Moreover, the attributes that define an agent extend beyond its toolbox. The dynamic approach can apply to each of these attributes.

For example, most LLMs have a token-selection attribute that controls how the system chooses the next token from the model output. Some of these

methods are associated with creativity, others with the response being precise. Although these two concepts are not accurately defined and measured, allowing the agent to dynamically control its token selection could significantly affect its ability to handle versatile tasks. Another attribute that can be changed dynamically is the base model of the agent. LLMs is a rapidly evolving field with new models coming out every week. These models vary in their capabilities, strengths and weaknesses. Allowing the agent to change its base model can allow it to adjust itself dynamically to the topic at hand, responding better to language, code, reasoning, and domain-specific tasks. The dynamic agent opens up new horizons in developing expert assistants, making them more adaptable, versatile, and capable.

3DOptix’ dynamic approach opened the path to create OptiChat, a highly capable optical design assistant. This assistant can perform various calculations, search for relevant optical elements in the database, conduct searches on the web, and execute major parts of the GUI commands in the simulation software – all through natural language. More importantly, this optics assistant can chain actions seamlessly. This enables the user to carry out complex operations easily, such as autonomously completing every step from calculating the required lens parameters to searching for them and running a simulation with them iteratively to perform a scan.

The traditional workflow of optics design in simulation software requires an adjustment period to the software

capabilities and limitations, and learning how to use it correctly. It requires manual search and calculations to find the right components, as well as a-priori knowledge or extensive research to understand the right order of actions. OptiChat allows a very steep learning curve and simplifies processes that require deeper understanding. With OptiChat, these more complicated processes can now be done by using simple, natural language, lowering the barriers to better optical design, as shown in Fig. 3.

To conclude: the dynamic agent approach allows the creation of revolutionary tools in optical design and many other domains. With OptiChat, any beginner can accelerate their learning curve and gain access to expert level tools and knowledge, paving the way for a better, intuitive optical design and usage of 3DOptix software.

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The importance of image quality in AI visual inspection systems

Why variability is the key challenge in model training

Sagi Dolberg



Source: Adobe Stock / xiaoliangge

The use of AI for visual inspection is currently making great strides in sectors like automotive, metals and machinery manufacturing. However, those investing in the technology not only expect a system that will be superior to manual inspection, but an error rate close to zero in defect detection. Let us look at the importance of image quality and why the variability in the production environment is the single greatest challenge that AI engineers must face.

Image quality is an essential factor in the performance of AI inspection models. It is crucial to the model training process and remains crucial when the model is deployed on the production line. Many customers expect an error rate of close to zero, in addition to less than one per cent false positives per camera. For comparison, the error rate for a human inspector, although varying depending on application, is typically above ten per cent, and some will argue even closer to twenty percent.

You cannot achieve these ambitious targets with poor quality images. A good starting point when considering the problem is feature extraction. Just like the human eye, the model is trying to extract as many features as possible

when looking at an image to detect the defect itself and then to classify or categorize it correctly. The more features we can extract from the image, the higher the probability of accurately predicting

▲ Robotic vision sensor camera system in a smart factory

what class of defect we have. Having high-resolution images is therefore

Company

QualiSense

Founded in 2022 in partnership with Cortica and Johnson Electric, QualiSense delivers a fast and scalable universally accessible augmented AI platform for production quality assurance that reduces the cost and time required to deploy automated inspection systems, and autonomously adapts to production and environmental changes with minimal human intervention. QualiSense is a software-only solution designed from the ground up for the production floor, offering high throughput, and easily integrates with any camera system for retrofitting to existing or new production lines. The company has several production systems serving top automotive OEMs, 18 patents pending and 14 in the pipeline.

<https://qualisense.ai>

Camera system for Industry 4.0 and technology concept



Source: Adobe Stock / xiaoliangge

important because this provides more details and features. Johnson's Criteria form the baseline criteria for our technology.

Named after scientist John Johnson and originally introduced in the 1950s for military applications, Johnson's Criteria were developed as the standard for detection, recognition and identification. They are calculated by establishing how many pixels are required to make an accurate evaluation of an object or image. We tell our customers that with anything below Johnson's Criteria, you cannot guarantee the KPI because the image quality will be too low. However, at the other end of the spectrum, there is the possibility that the image resolution is too high. Improving the resolution of the image is generally a good thing for the reasons mentioned above but, after a certain point, additional pixels simply slow down the inference pipeline on the GPU. This process is measured in milliseconds in many applications that we are dealing with, so if the image resolution is too high, various techniques are required to adjust the image and maintain the correct speed in the inference process.

Another factor worth mentioning when discussing image quality is

color depth. Images can represent a wider scale of shade and a higher color depth. When combined with high resolution, this enables the distinction between two very similar, although not identical, objects. We work with grayscale in many of the applications we are currently dealing with, though, either because the camera is grayscale or because the object itself does not possess any color, such as a metal part for example.

The next factor to consider is contrast and sharpness. Although these are similar and therefore worth grouping together, there is a subtle difference because sharpening refers to the contrast only at the border or edges of objects. Greater contrast can make it easier to distinguish between the background and foreground, and with a sharper image, you can more easily distinguish between a crack and a watermark for example.

Overcoming challenges

One of the key challenges in building an AI model that can accurately detect and classify defects is the availability of data for training. Unlike LLMs, which can be trained on open-source data from the Internet, building an AI model for quality inspection requires data taken from

a production environment. At QualiSense, we have overcome this challenge through our partnership with Johnson Electric who provide us with access to extensive proprietary data from the production environment to develop a strong and effective backbone.

However, even this vast amount of data would not be sufficient by itself. When building a model, you try to test it against worst-case scenarios, and those that you hope ultimately will not be encountered in the production environment. Without training the model with outliers, rarer defects will slip through the detection net. Carrying out augmentations to get more from the existing data is therefore an essential part of the process. For example, if you had an image of a part, you might flip it round to create another image of a part in reverse, giving yourself more data for training and exposing the model to variability.

The problem of noise is unsurprisingly a common one when dealing with image quality in quality inspection. Humans can filter out noise more easily than machines. Noise can obfuscate or take away the information the model needs to carry out visual extraction. A noisy image can represent something differently, providing false clues or signs



Source: Adobe Stock / kwanchaifit [AI generated]

Machine learning algorithms applied to predictive analytics

of things that do not exist in reality. To overcome this challenge, it is necessary to introduce noise as a preprocessing technique or an augmentation.

Noise is a challenge in any computer vision model, but there is a unique challenge if you are building a model for production and quality inspection: there is high level of variability in the production environment. An AI model is better at detection than the human eye, but it struggles more with the variability aspect. For example, minor changes in the lighting, the appearance of a shadow, or a small change to the conveyor are all examples of common changes in the production environment that can create problems for the camera and the AI model.

This variability is arguably the single greatest challenge that AI specialists need to overcome to build a successful model for quality inspection. To meet the customer's KPI, the model must be very sensitive and able to detect not only the most common defects, but also rare defects and outliers. However, if the model is too sensitive, then minor

changes in the production environment will require significant updates, requiring more time and investment from the quality manager.

Much like with noise, the keys to overcoming this when you are doing the inference pipeline on the production line are sophisticated preprocessing and augmentation to provide a high level of variability in the training process, and to ensure that the model is not overly sensitive to changes in the

production environment. If we look at previous attempts to automate quality inspection of complex inspection tasks, it has often been this variability challenge that has resulted in a long and tedious process of continually updating the model. Thankfully, we are now building the next generation of AI models that have the sophistication to overcome this hurdle.

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Machine Vision

Early view article, now online and in PhotonicsViews issue 5/2024

3D vision helps to precisely palletize parts

Reliable part recognition allows the entire workflow to be optimized and automated, which speeds up palletizing, saves costs, and relieves employees

The Spanish robotics specialist Tekniker has developed a solution that allows chaotically lying parts to be automatically gripped from containers and placed in other containers in an orderly manner. The integrated MVTec Halcon 3D vision software ensures precise gripping of those parts.

Tekniker, based in Eibar in northern Spain, specializes in the development of technology solutions for automation, industrial robotics, and sensor technology, among others. The company serves a wide range of industries such as aerospace, automotive, or machinery and plant engineering. One of Tekniker's customers is the Cikautxo group, a Spanish manufacturer of vibration-damping and fluid-conducting components for the automotive industry. On behalf of the company, Tekniker's team of experts has developed a machine vision-controlled robot system for the automated palletizing of compo-

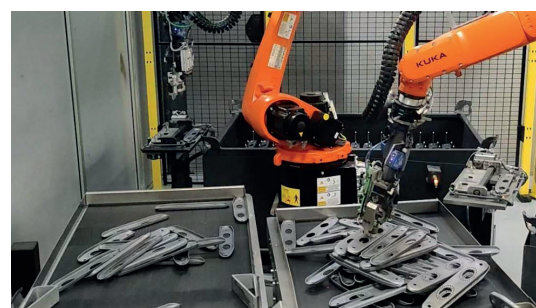
nents for industrial production. Robots remove components that are lying randomly in a box and then place them in an orderly manner into a container that is specially adapted to the geometric features of the parts. They are then ready for further processing in the production workflow.

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The machine vision solution enables two robots to pick up the components in parallel

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AdheScan – adhesive failure surface inspection system

Adhesive failure surface evaluation based on machine learning of high-resolution stereo images

Luca Kuhlmann, André Lamott, Armin Thomsen, Heiko Mühlenfeld-Keßler, and Anja Knigge



All images source: Schäfter+Kirchhoff

Adhesive bonding is an established joining technique with many applications in for example aerospace, lightweight construction, and the automotive industry. It places particularly high demands on materials, processes, and quality assurance, requiring extensive development and qualification procedures. Many process samples generated for testing are still evaluated manually by experts. The AdheScan provides a quantifiable, simplified and more accurate evaluation of adhesive failure surfaces.

The AdheScan inspection system is an advanced, user-friendly laboratory instrument for the evaluation of adhesive failure surface inspection assisted by machine learning algorithms. The system is designed to use expert knowledge in an objective and reproducible way. It is based on a specially designed image acquisition system combined with trainable machine learning algorithms. The overall goal is to provide a quantifiable, reproducible, and simplified evaluation of adhesive failure surfaces, combined with the ability to digitally store the data. Bonding professionals will finally have quantified,

accurate data that allows for further systematic research and development.

Adhescan is a further development of a demonstrator, that was developed in cooperation with Fraunhofer IFAM (Department of Adhesion and Interface Research & Quality Assurance and Cyber-Physical Systems) in a project (SAMBA, 20Q1924A) that was publicly funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK). The customization for this particular application and the implementation of the machine learning algorithm was made possible through close collaboration and knowl-

▲ **Fig. 1** AdheScan – a complete inspection system for the machine learning assisted adhesive failure surface inspection. Shown here is the device in the preliminary housing, which will be also presented at the Vision 2024 show

edge sharing. The patent is pending (not yet published).

State of the art evaluation

While adhesive bonding is a standard technique, it is essential to recognize that the bond quality cannot be evaluated in its entirety using nondestructive methods. This means that the

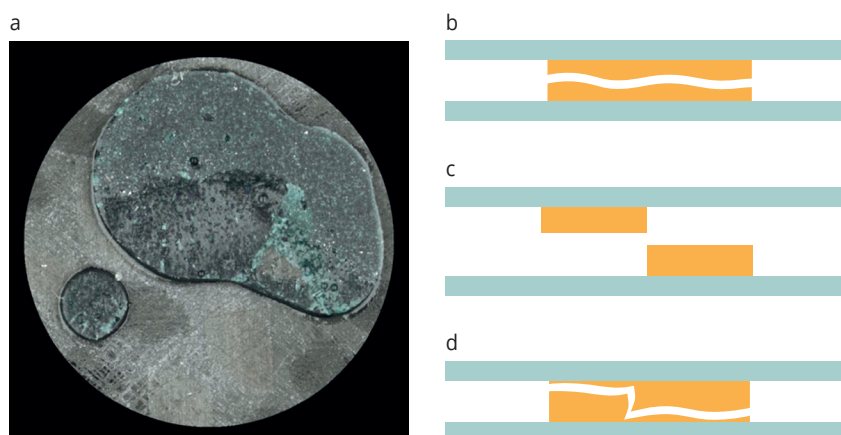


Fig. 2 High-resolution image of the stamp (a) and schematic drawing of common adhesive failure types. The sample exhibits both cohesive (b) and adhesive failure (c). Another common type is cohesive failure near the surface (SCF, d). Shown samples are courtesy of Fraunhofer IFAM

materials, process and quality assurance requirements for this joining method are particularly high, as it is often used in safety-related components. For this reason, extensive development and qualification procedures are required, during which a large number of process samples are produced for mechanical testing.

The samples shown in this article are all courtesy of Fraunhofer IFAM and were all manufactured by bonding a substrate to a stamp. They were then placed in a centrifuge until the adhesive fails to bond.

An important indicator for evaluating the bond is to know when the bond fails, i.e., at what force the bond breaks. Fig. 2a shows a high-resolution image of a standard sample. The different failure types are defined according to DIN EN ISO 10365: 2022, Adhesives – Designation of main failure patterns. Typically, the bond is optimized to break in the adhesive (so called cohesive failure

CF, Fig. 2b) rather than at the interface (so called adhesive failure AF, Fig. 2c). Among others, another possibility is cohesive failure near the surface for example (SCF, Fig. 2d).

Once the samples are prepared an expert determines which parts of the sample can be assigned to which failure type. Currently, this is done manually by experts relying on few standard procedures. One method is to visually inspect the two parts involved in the failure and estimate and note the area percentages. An image is then taken under a microscope and the values are documented manually.

Another option is to place a grid over the samples and then estimate the area percentage for each grid point, which increases reproducibility and makes the assessment a little less subjective. Overlaying the grid can be done with a film or an image of the sample. In both cases, the samples must be physically available for evaluation.

A third option is to take an image with a microscope. While the reproducibility and accuracy are high, the evaluation by marking and counting pixels is time-consuming. Because the fracture pairs are not evaluated together, the fracture surfaces may be incorrectly assigned.

How do bonding experts benefit from AdheScan

AdheScan provides reproducible, quantifiable results for common adhesive failure patterns. It uses two line scan cameras by Schäfter+Kirchhoff (type SK4k-U3DR7C, color, pixel size 7 μm) and provides a high-resolution image at 11 μm optical resolution of both surfaces of the fracture pairs. The cameras are used in a stereo configuration to provide additional valuable height information with a resolution of 20 μm . A 3D representation of the sample is

generated by combining the images with the height information. The standard system scans up to eight adhesive failure pairs (eight pairs of substrate and stamp) in less than 45 seconds and calculates the height information in approximately 20 seconds. The complete AdheScan is depicted in Fig. 3a. A typical sample holder with eight fracture pairs is shown in Fig. 3b. It is also possible to scan different types of samples with the help of a customized sample holder.

The high-resolution image and the height information provide the basis for the subsequent evaluation

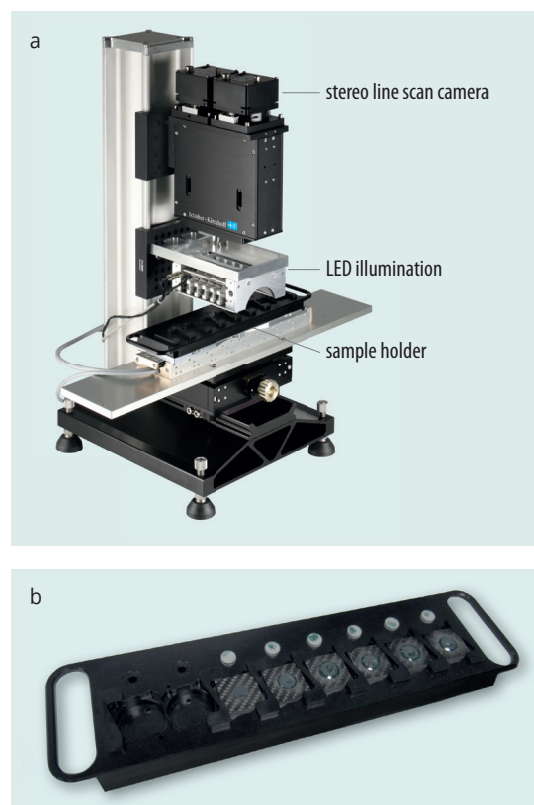


Fig. 3 (a) Previous demonstrator from which the AdheScan was developed with stereo with stereo line scan camera, LED illumination, specialized sample holder. (b) The sample holder with six fracture pairs

Company

Schäfter+Kirchhoff

Schäfter+Kirchhoff has accumulated substantial experience in the development of optomechanical and optoelectronic systems for use in research, aviation and in space, as well as for demanding medical and industrial applications. Schäfter+Kirchhoff design and manufacture their own line scan camera systems, laser sources, beam-shaping optics and fiber-optic components, including laser beam couplers, fiber collimators, and fiber port clusters for customers worldwide.

www.sukhamburg.com

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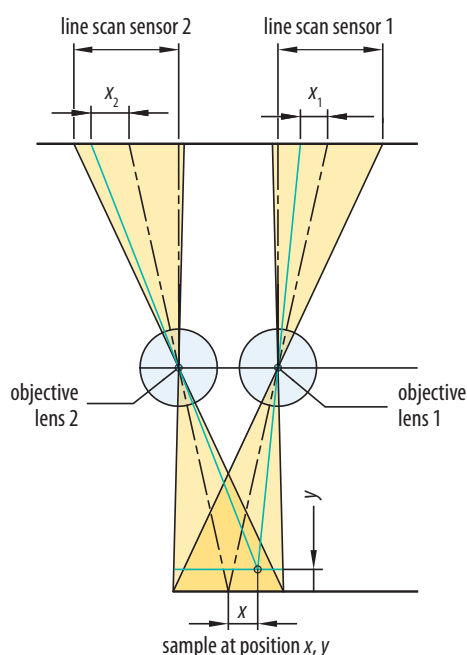


Fig. 4 Schematic drawing of a stereo line scan camera configuration. A high-resolution image is acquired by each line scan camera. The disparity $x_1 - x_2$ is then used to acquire the height evaluation for each sample

using a machine-learning algorithm. The software allows the user to easily train the machine-learning algorithm to automatically evaluate samples in seconds. A well-trained algorithm has a processing time of only about 4 seconds for the evaluation of one pair of samples, depending on the computer hardware.

What is a stereo line scan camera?

A stereo line scan camera configuration is shown in Fig. 4. The two line sensors are positioned parallel to the sample surface. A difference in height (y)

results in a difference in pixel position (x_1 on sensor 1 and x_2 on sensor 2). This so-called disparity $x_1 - x_2$ is the basis for the height evaluation of the image. A complete 2D image of the surface is acquired by moving the object under the two line scan cameras (e.g. from left to right). The disparity in the line scan signal for each position then provides height information for each sample point. A high-resolution 2D image of the surface and a height profile are measured simultaneously. The software then uses these two features to generate a 3D image for each sample.

Surface failure inspection using AdheScan

The normal procedure for evaluating a set of samples with AdheScan includes several routines inspired by practical experience, e.g. a previously defined region of interest (ROI) set and the input of meta information such as the adhesive used and the substrate materials. A high-resolution image is acquired, and an image with height information is calculated from the scanned images and stored.

Since the sensors scan the entire surface, the images are cropped according to the defined ROIs and displayed in a 2×2 view. It shows the two high-resolution images of the two fracture halves – the substrate and the stamp – along with the corresponding height information. The software then supports the alignment of the images to each other. This is especially important because all four images (high-resolution and height image) must be considered and evaluated together to achieve the highest possible accuracy. This is done via a dialog where the user can align

the images with the help of a special visual representation. After alignment, the superimposed camera image is used to create a rotatable 3D image.

Fig. 5 shows a pair of substrate and stamp fractures after alignment. The first row shows the high-resolution images of both the substrate (a) and the stamp (b), the second row shows the acquired height information for both the substrate (d) and the stamp (e), while (c) and (f) show the corresponding 3D images of both the substrate and the stamp.

The samples can now be annotated, which means the different fracture surface areas are marked. This can be done either manually using the annotation tool or using a trained algorithm in process mode.

The annotation tool allows the image to be described according to user-defined label sets for the expected fracture surface patterns (e.g. adhesion fracture AF, cohesive fracture CF, etc.), which can be seen in Fig. 6. The labeling of the sample is performed in parallel in both the height and high-resolution images, and is displayed simultaneously in the 3D image. This allows the surface to be annotated based on the most convenient identification points. In this way, all significant features from all four images (both high-resolution and height images of the substrate and stamp) are considered and evaluated together during the marking process. This greatly increases accuracy, especially compared to manual evaluation where only one image of a sample is considered at a time.

An algorithm then uses the pre-marked features to calculate the final results. Even with only a few markers,

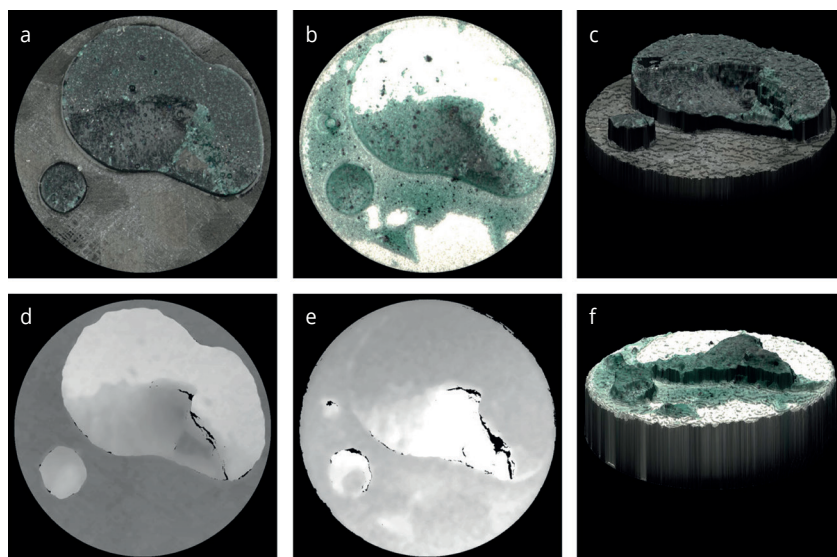


Fig. 5 High-resolution images of both substrate (a) and the stamp (b), height information for both substrate (d) and stamp (e) as well as the corresponding 3D images of both substrate (c) and stamp (f)

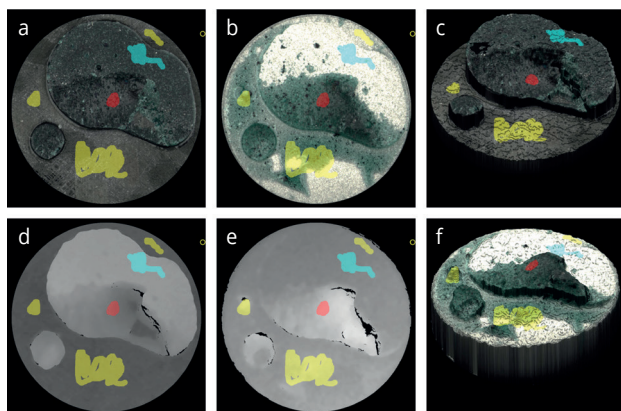


Fig. 6 Annotation tool. The user marks the fracture classes where the surface is easiest to identify in either both high-resolution image (a, b), or the height image (d, e). All other images are marked live for more accurate results

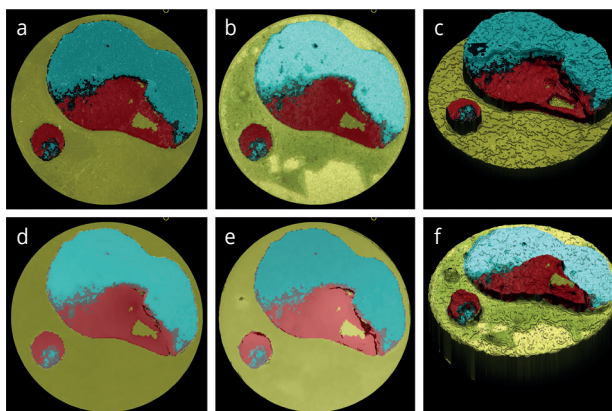


Fig. 7 Identified fracture types for both substrate (a, c, d) and stamp (d, e, f) in both high-resolution image (a, b), height image (d, e) and 3D image (c, f)

the algorithm can make a prediction for the entire image, as shown in **Fig. 7a-e**. The complete image is now divided into the corresponding fracture patterns according to the predefined labels, e.g. 25 % CF, 35 % AF and 40 % customized failure type. The software provides several in-depth features such as histograms, heat maps, etc. to evaluate the quality of the result. A threshold value can be defined to determine whether the analyzed sample is considered a reject. All results are logged and all relevant data is stored in a database for easy retrieval of previous results.

The annotated images can then be selected as a sample set to train the algorithm. For verification, a portion of the training set is evaluated with the trained algorithm and compared to the manually evaluated results. If the result is good, the training of the algorithm can be completed by releasing it and it can then be selected in process mode to use the machine-learning algorithm-assisted fracture inspection.

The system scans up to eight adhesive failure sample pairs in under

45 seconds and calculates the height information in approximately 20 seconds. Depending on how well the features of both sides are visible in relation to each other, rotating and aligning the samples can take anywhere from 30 seconds to 2 minutes. When evaluating samples manually, the time may vary from user to user, depending on the desired accuracy and the number and identifiability of fracture patterns. In general, the evaluation can take between one and five minutes. In process mode, the trained algorithm takes over the evaluation of the images after the user has aligned them properly. For a typical image size of 900×900 pixels, the algorithm needs about four seconds to evaluate the sample. However, this depends on both the image size and the processor performance.

Conclusion

AdheScan finally provides valuable and reproducible data for bonding professionals as a basis for further research and development. Experts can mark the identifiable fracture patterns based on

the high-resolution images and height information. The algorithm is then trained using these annotations and further inspection is quick and easy. A prediction mode was developed for laboratory use when dealing with very frequently changing substrate/adhesive samples. In process mode, the large number of samples, e.g. in-process samples, can now be evaluated in an efficient, reproducible, and accurate manner.

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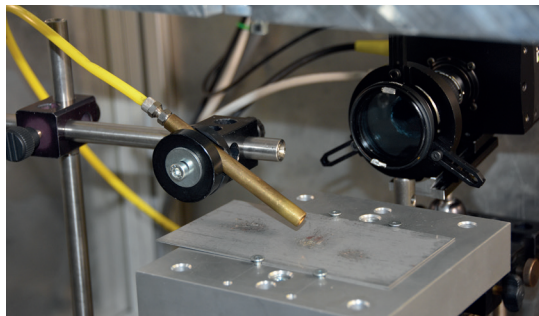
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Laser cleaning of insect residue without surface alteration

A pulsed CO₂ laser provides an effective shockwave-based cleaning process



Insect residues disturb and interrupt the laminar air flow on airplane wings after a while. These residues therefore need to be repeatedly removed. Shockwave-based laser cleaning of insect residue on stainless steel (1.4544.9) is presented as a possible method to reduce insect residues in a single pass and without influencing the base material, as confocal laser-scanning microscope images demonstrate.

Shockwave-based laser cleaning of insect residue was performed using a ML105E pulsed nanosecond TEA CO₂

laser from SCLR Lasertechnik. The beam was emitted with a wavelength of 10.6 μm over a pulse duration of 100 ns and at a frequency of 10 Hz. The beam had a rectangular shape and was guided by a concave focusing mirror onto the target's surface, which was made of stainless steel 1.4544.9.

The target was placed on an x-y table of type KT310-200 produced by Steinmeyer Mechatronik that performed the movement of the target to enable the areal cleaning process using a meander path, a pulse overlap of 33 % and a path overlap of 30 %. Prior to the first cleaning pass, the residue was imaged with an Olympus BX53M with a 2.5-fold lens by single images stitched together to provide an overview. Images were taken at 10-fold magnification for a more precise depiction of characteristic locations within the residue using a confocal laser-scanning microscope of type VK-X 3000 produced by Key-

ence. After the first and second pass, the imaging was repeated to visualize the cleaning progress. The images were analyzed using the MultiFileAnalyzer software, also provided by Keyence.

According to microscope images, the cleaning process shows a great cleaning effect after a first cleaning pass due to a significant reduction of the insect residue in volume and height, and with the potential to remove all of it after multiple passes.

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Optimized powder bed laser melting processes

Stable processes are a challenge – machine vision provides insights and enables better control



Various disruptive phenomena such as melt pool turbulence, welding fume formation, spatter, or other anomalies, make it difficult to monitor and control PBLM processes.

The goal of Aconity3D is to optimize the stability of an innovative manufacturing method called powder bed laser melting (PBLM) and to promote its use in a wide range of industries. By utilizing high-speed industrial cameras from SVS-Vistek, the company has come one step closer to this goal.

The main problem with PBLM compared to conventional methods is that

the manufactured part can only be checked for defects once it is unpacked from the surrounding powder material at the end of the process. If there are defects at this stage, they are generally almost impossible to rectify.

In order to change this situation, Aconity3D has developed a process in which the data from a high-speed machine vision system helps to record the influence of selected process parameters on produced parts and enable conclusions to be drawn about parameter influences."

Aconity3D opted for the Mikrotron EoSens3.0MCX5 high-speed camera from SVS-Vistek and the necessary peripherals for this task to implement a system suitable for daily use. When the company started researching the market for suitable cameras with the required speed and accuracy for this application around six years ago, there were no comparable cameras available. The camera has been absolutely stable since its intro-

duction and provides an insight into the correlation of sensor data, the applied process parameters, and the resulting component properties.

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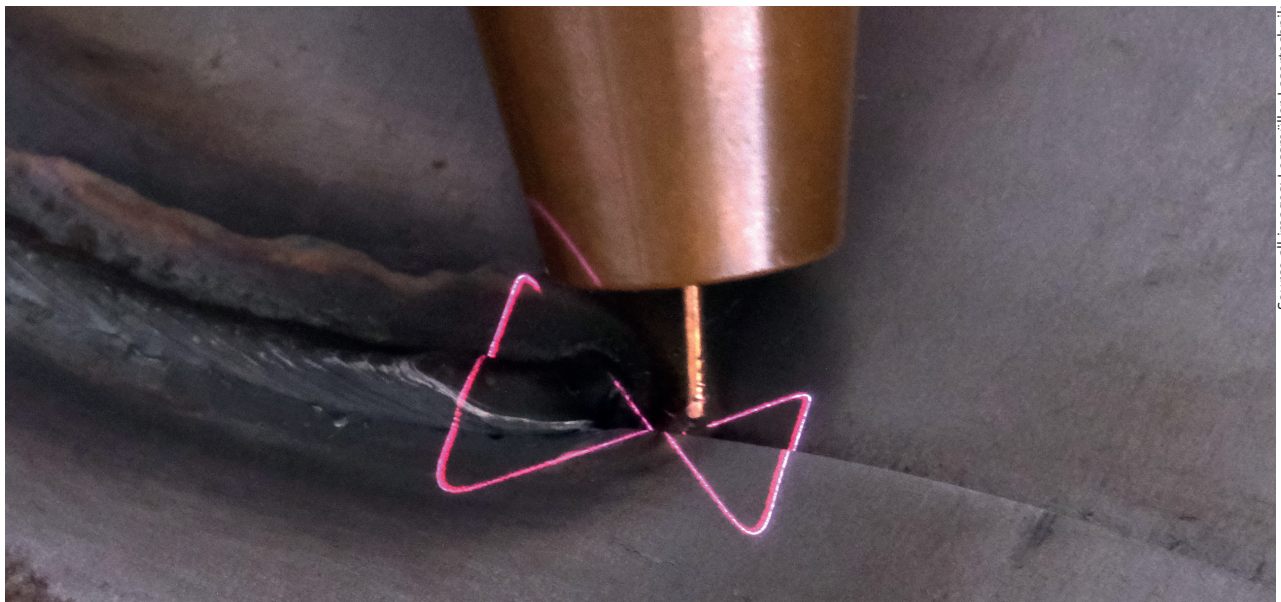


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OCT for automated conventional welding in the automotive industry

Optical coherence tomography provides robotic GMAW with a process and quality monitoring function

Nataliya Deyneka Dupriez & Samuel Adolph



Source all images: Lessmüller Lasertechnik

Similar to laser welding, optical coherence tomography (OCT) simplifies the operation of robot-guided, automated GMA welding by offering seam tracking capabilities thanks to its industry-approved, standardized functions and fieldbus communication. Furthermore, OCT can monitor the quality of weld seam online by measuring the seam topography during GMA welding, eliminating the need for time-consuming and costly off-line weld inspection.

Gas metal arc welding (GMAW) is known as the standard welding technique for ferrous and aluminum alloys. It produces high quality, strong, and reliable welds that can withstand various loads and stresses. This makes it a popular choice for applications where strength and durability are critical.

In the past, many large parts were welded by hand. Nowadays, this work is carried out by robots at automotive suppliers that can weld them automatically or semiautomatically on the assembly line. Robot-operated GMAW is boosting the production of electric vehicles. It allows different metals and alloys to be joined at high welding speeds, increasing production efficiency. As wire is always fed to the parts being

joined during GMAW, larger gaps can be bridged and the edges need to be prepared less precisely compared to laser welding. It is therefore the first choice for larger parts with wide weld beads.

The welding process must be precisely controlled in order to further improve the productivity of automated GMA welding and reduce the risk of a lack of fusion. Previous process monitoring systems were considered insufficient due to the high performance requirements of robotic GMAW. OCT has recently become widely used for real-time control and process monitoring of laser welding [1]. Coaxially directed onto the workpiece surface together with the processing laser

Company

Lessmüller Lasertechnik

As one of the leading experts in laser process monitoring, Lessmüller Lasertechnik offers standard and customized solutions for live process monitoring and control of industrial laser processing, all developed, designed and manufactured in house and installed worldwide: the innovative OCT with more than 200 installations for flexible, precise, and reliable seam tracking, weld depth measurement and seam inspection, allowing a step forward in faster, more accurate and effective production; the proven WELDEYE with over than 800 systems, and the economical WELDCHECK for process monitoring.

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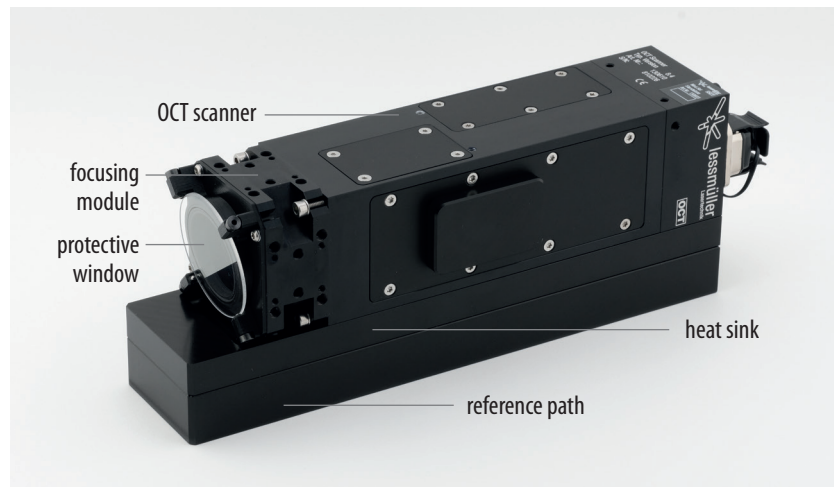


Fig. 2 Standalone OCT scanner with integrated reference path and protective window

beam, the OCT beam enables topographical surface examination in pre, in, and postwelding process. It provides transparent information about the positioning status of the optics and the workpiece, as well as the weld quality. The advances in OCT technology can be transferred to GMAW, enabling accurate and consistent seam tracking and inspection suitable for the mass production of automotive components.

Standalone OCT system

The non-contact OCT system is a compact complete system that enables high-precision process monitoring and quality assurance in real time. Rather than being mounted on the laser welding optics, the OCT can also be used as a standalone measuring system for quality monitoring or in welding systems without welding optics, such as arc welding. The standalone OCT made by Lessmüller Lasertechnik consists mainly of an OCT scanner with an OCT reference path, an OCT sensor and OCT IPC. The reference path is integrated into the OCT scanner as a separate water-cooled module on the side of the OCT scanner (Fig. 2). This design makes it possible to avoid measurement errors due to the temperature difference between measurement and reference paths.

In addition, the standalone OCT scanner is equipped with a focusing module containing a focusing lens with focal lengths – and thus nominal working distances – of 300 mm, 400 mm, or 600 mm available. This yields a lateral scan radius of the OCT scanner up to 25 mm, 35 mm, or 55 mm respectively, depending on the optical conditions. The resolution of the detected position is typically 5 μm . The minimum radius

of the contour analysis area during seam inspection is 0.25 mm.

The configuration range of the working distance also depends on the focusing module that is: ± 50 mm for 300 mm and 400 mm focusing lenses, and $-150/+50$ mm for the 600 mm focusing lens. The axial measurement range of the OCT is max. 12 mm in all configurations.

If the OCT scanner is mounted on the welding gun, material particles or material vapors can be deposited on the OCT scanner during the welding process. As the OCT system accurately detects the position of the joint and inspects the weld bead, accumulated traces of dirt on the focusing lens can lead to pseudo-faults or completely disturb seam tracking. In this case, the focusing lens of the OCT scanner must be protected by a replaceable protective window (see Fig. 2).

The OCT sensor contains a low-coherent light source and a spectrometer. The OCT IPC serves for communication with the OCT sensor to record and evaluate the measured OCT data. As extremely large amounts of data are generated when welding numerous workpieces, and the local storage space on the OCT IPC is limited, it is possible to transfer the recorded data while welding to a network memory for documentation and post-weld analysis.

The OCT IPC is equipped with a PCI card for fieldbus communication with the robot. The OCT system detects the joint, analyzes the actual edge location versus the programed robot location, and controls the robot movement by working with PLC and interfacing with a robot such as a Fanuc or Kuka. The standalone OCT can also be applied for the online and offline detection of the weld seam defects. The

OCT immediately signals to the PLC if the detected seam topography or faults are out of specification.

Setup of GMA welding with OCT

Instead of the camera systems currently used, OCT technology can be applied for gas metal arc welding to perform direct optical height measurements during the mashing process. The OCT scanner can be mounted directly on the arc welding gun (see Fig. 3). Usually, two OCT scan lines are projected near the welding area (Fig. 1): one prior to the torch nozzle – or arc – that scans across the joint, and one directly behind the arc that scans across the

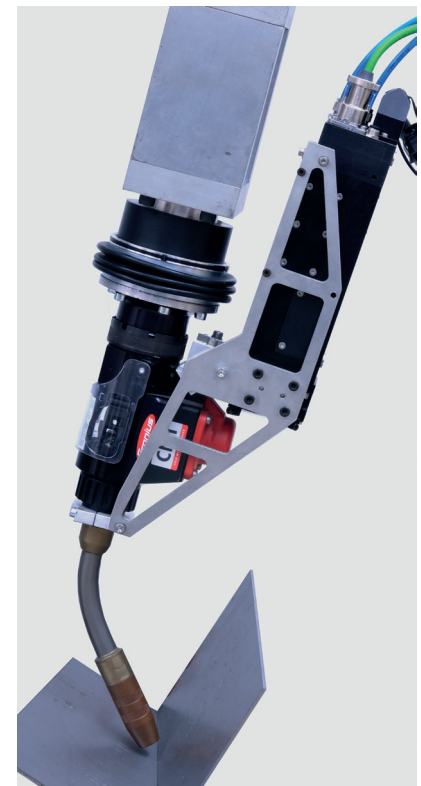


Fig. 3 Robotic GMA welding gun with OCT scanner for online process and quality monitoring

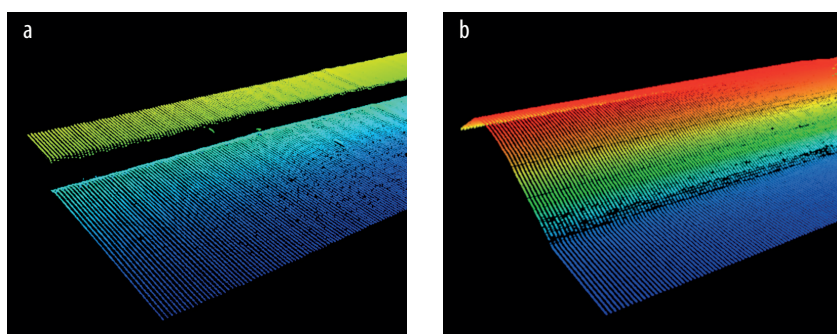


Fig. 4 3D surface topography obtained by OCT scanning over (a) the lap joint in the preprocess and (b) the solidified weld in the postprocess

weld bead. The length of the OCT scan line in front of the arc is typically between 10 and 15 mm to enable reliable tracking, while the line length behind the arc varies in the range of 15 to 20 mm to ensure inspection of the entire weld.

Scanning before welding enables precise and fast online determination of the lateral and axial joint location and orientation (Fig. 4a). This information is used for real-time seam tracking, as the actual seam trajectory deviates slightly from the programmed robot movement path. The OCT system takes control of the robot by sending it the offset values from the original robot path to the found joint position in order to move the robot along the joint during welding. The OCT scan lines are rearranged in accordance with the welding direction [2]. OCT can also send the weld angle corrections if required.

The distance to process from the seam tracking line is set to 7 – 10 mm. This distance is critical: a smaller distance increases the accuracy of the weld location; the closer the line is to the arc, the faster the reaction to deviations in the joint position. This is even more important for sharp changes in direction or circular robot movements. However, the accessibility of the OCT beam is limited by the torch nozzle diameter, and faster welding speeds require a greater distance to the arc due to the communication time between the robot and the OCT system.

The OCT scanning angle has to be selected in such a way that the accessibility of the OCT beam – especially at the T joints – and the visibility of the edge and the gap is guaranteed. For reliable joint detection and gap measurement, an angle of at least 82° towards the lower blank of the T joints is required.

Simultaneously, the OCT system scans the already solidified part of the seam that was melted by the arc. Similar to laser welded workpieces [1], the acquired surface profile (Fig. 4b) is used

for seam inspection to examine the seam geometry, detect undercuts, pores, craters, silicates, and other defects and, for example, to check the overlap of the weld seams. The OCT scanning angle can be adjusted to improve the visibility of porosity in the OCT image.

The distance between the seam inspection line and the arc is limited by the melt pool length and the welding speed and needs to be adapted to the specific process. The seam inspection line has to be as close as possible to the arc to ensure the visibility of the

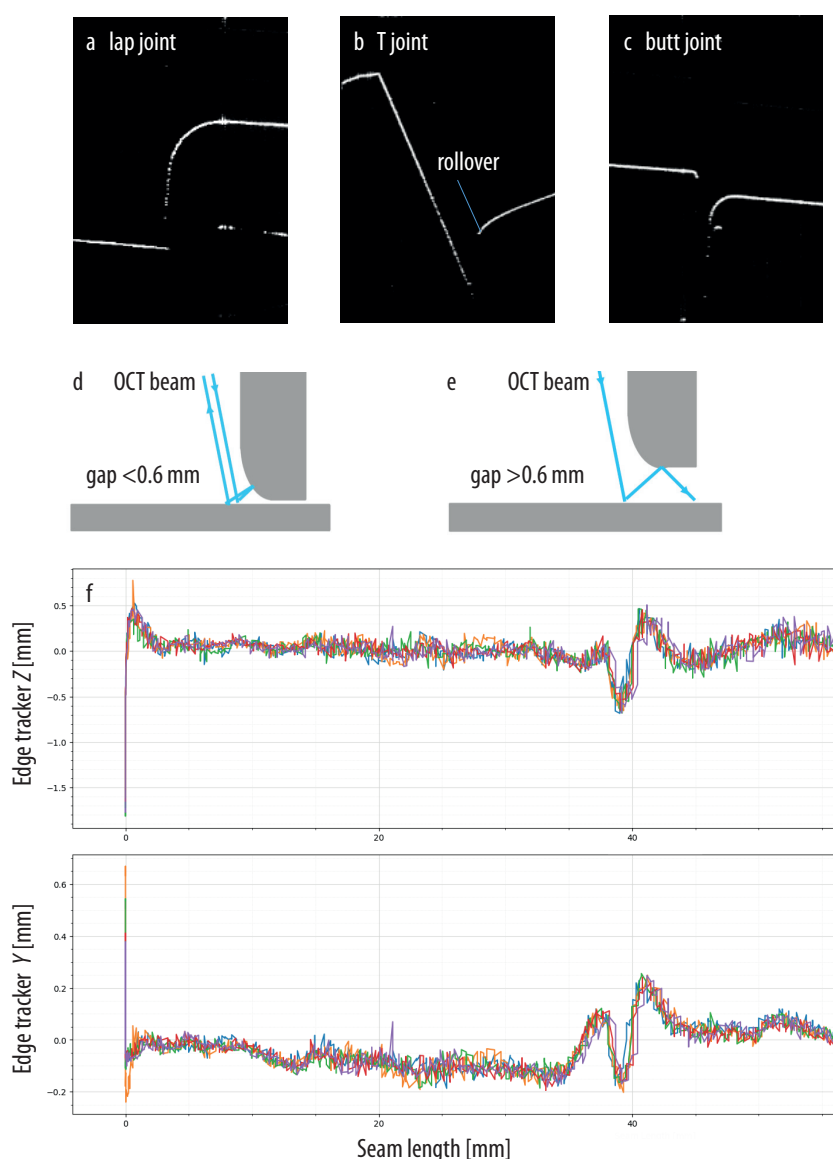


Fig. 5 Typical OCT images of the surface profiles of (a) lap, (b) T and (c) butt joints taken on the automotive workpieces. Such images are used for edge tracking with a high degree of repeatability (f) even at the sharp changes in the weld direction (see spike) to ensure reliable seam tracking and weld inspection. (d-e) Gap detection in the T joint that is possible for gaps larger than 0.6 mm due to the multiple reflections of the OCT light at the rollover and at the gap.

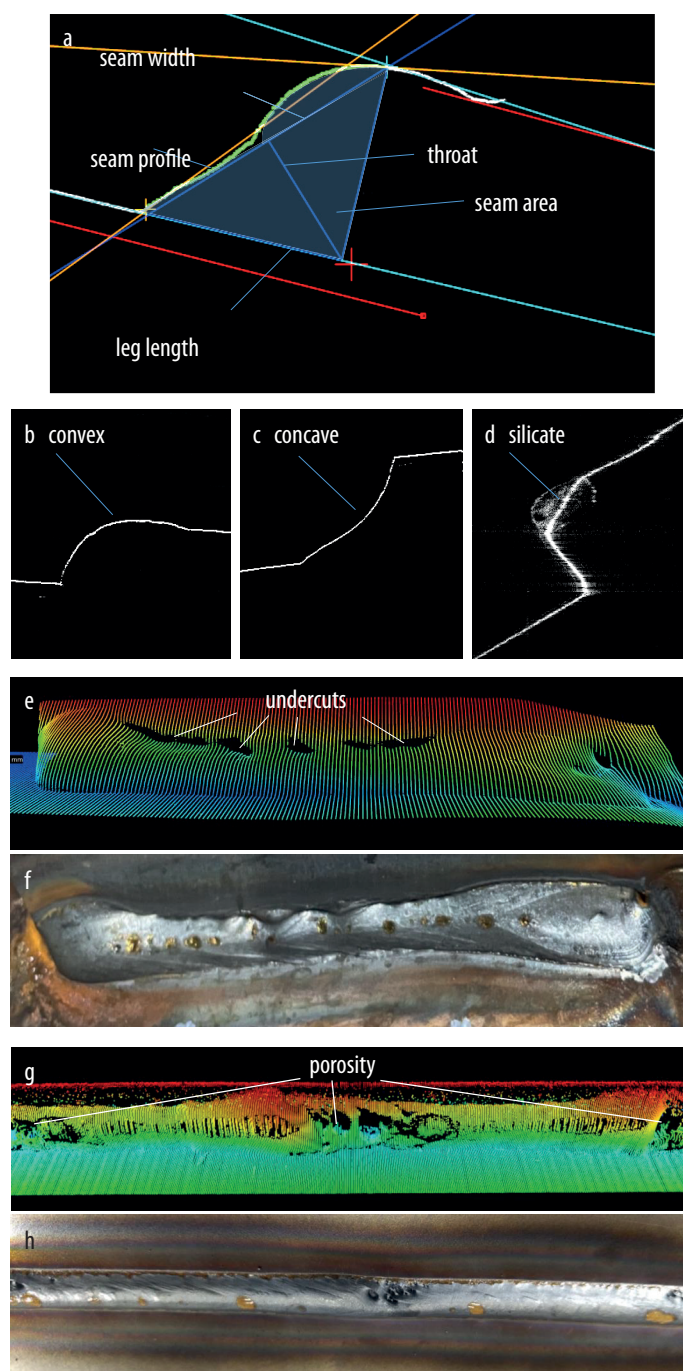


Fig. 6 OCT images of the measured weld topography with (a) an example of the evaluation of the weld geometry; (b) convex and (c) concave seam profiles; examples of weld defects such as (d) silicate, (e) undercuts, (g) pores, and (f, h) corresponding photographs of the weld

weld failure. However, complete solidification of the seam is crucial, as molten and very hot solidified material causes diffuse reflection and therefore poor OCT signal quality; faster robot speeds may require greater distances to achieve constantly good signal quality at all points.

Customized software developed by the Lessmüller Lasertechnik team provides the user with algorithms for edge tracking and seam inspection for the acquisition, video recording and evaluation of the pre and post-welding process.

Testing the feasibility of OCT with arc on during GMAW

The aim of this work is 1. to investigate the capability of OCT technology for real-time seam tracking and weld seam quality assessment during robotic GMAW of automotive parts made of bare steel, coated steel, and aluminum at a robot speed of 0.5 – 2 mm/s, and 2. to demonstrate a fully functional automated system for weld seam detection and inspection.

The OCT system was tested for finding three joint types – namely lap,

T, and butt joints – during arc welding of workpieces from automotive suppliers (Fig. 5a-c). Under the measurement conditions defined above, a good quality OCT signal is obtained in each case. Fig. 5f demonstrates the repeatability of the detection of the joint position and thus the seam tracking, especially in the case of abrupt changes of the seam trajectory (visible as a spike in Fig. 5f because the robot has to reposition the welding gun with help of the OCT).

As previously stated, the OCT system enables measurement of the gap and gap bridging [3]. In case of a lap joint, the recognizable gap is limited by an OCT focus range of ± 6 mm. Therefore, the gap size together with the thickness of the top sheet must be less than 6 mm. The accuracy of the measured gap in the lap joint is found to be less than 0.1 mm for a gap of up to 2.5 mm, which ensures the repeatability of measured gap detection below 0.005 mm.

For a T joint with rollover (see Fig. 5b), the accuracy of the gap measurement depends on both the gap and the rollover size, as the entire rollover is not visible for OCT. The rollover limits the smallest detectable gap size to 0.6 mm because reflections in the gap cause inaccurate measurement of the gap size (Fig. 5d). If the gap is large enough (greater than 0.6 mm) the reflections are not deflected back and are not detected by the OCT (Fig. 5e). The accuracy of the measured gap in the T-joint is estimated to be less than 0.2 mm (including rollover) with a repeatability of <0.05 mm.

The robotic welding system is usually able to adapt the robot's program sequence to bridge the gap, either by adjusting the offsets or the welding angle or a combination of both, depending on the joint type, gap and rollover size.

When integrated with robotic GMAW, OCT performs real-time weld seam verification. The system is able to inspect the relevant visual weld defects presented below. If the evaluated seam characteristics are outside a predefined tolerance range, the OCT system reports the faulty weld or even sends an alert to stop the process, in accordance with customer requirements.

OCT is deployed to automatically check the weld length: it detects the start and end point of the welded seam, combines it with the coordinates obtained from the robot, and calculates

the actual weld seam length. For a circular weld, the total weld seam length is determined as a sum of subsequent short steps seam lengths. It measures the weld seam geometry: seam width and seam area, leg length and throat (see Fig. 6a) and supplies the customer with the numerical data. The profile of the weld bead, convexity, or concavity (Fig. 6b-c), is analyzed to determine whether it complies with the tolerances. It is possible to recognize undercuts that appear on the OCT image in form of notches on the sides of weld bead (Fig. 6e-f). Silicate can only be identified – but not reliably – if a characteristic double line (Fig. 6d) is present in the OCT results (e.g. depending on the scan quality, the transparency of the silicate). Surface cracks, porosity and craters are also visible on the OCT image of the seam surface (Fig. 6g-h) and can be evaluated.

It has been experimentally proven that smoke does not affect the OCT signal quality. Flying spatter is rarely detected with OCT, which is visible in

the resulted image but has little effect on automated seam tracking and weld inspection.

In general, the application of automated seam tracking and online seam inspection with OCT during welding guarantees a reduced scrap rate and the need for separate quality control after welding. OCT then provides robot-guided GMAW with a process and quality monitoring function that makes it cost-effective, highly productive and efficient, with good economic results for the production of durable structural parts of automobiles, including electric vehicles.

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- [3] N. Deyneka Dupriez: *Laser Tech. J.* 15 (2018) 3: 46-49; DOI: 10.1002/latj.201800018

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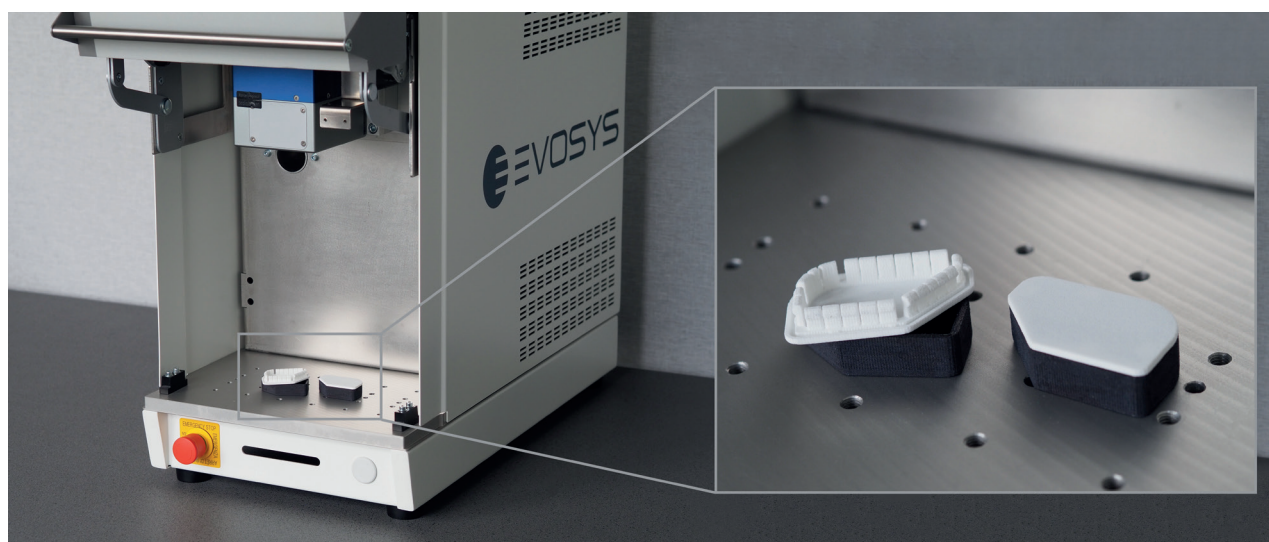
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Flexible laser plastic welding as an addition to AM

Highly efficient welding of additively manufactured thermoplastic components

Lea Kroth, René Geiger, Sebastian-Paul Kopp, and Katja Tangermann-Gerk



Individualization, shorter product cycles and prototyping are leading to increased use of additive manufacturing in industry. A reliable and versatile process like laser plastic welding is needed to join parts with other additively manufactured or injection molded parts.

Additive manufacturing (AM) is nowadays a standard process in industry. The applications range from the individualization of mass production to small series parts and prototype construction. Flexibility, form freedom and

short cycle times are only a few of the advantages this process offers. Additive manufacturing is even more economical than injection molding (IM) for small quantities due to the short time from model to functional part, and additional tooling being unnecessary. A commonly used process variant in the industry is laser-based powder bed fusion of polymers (PBF-LB/P), also called selective laser sintering (SLS). In this variant, polymer powder is applied layer by layer and selectively melted with a laser which, for example, enables the construction of light-weight structures or undercuts, both of which are not possible with injection molding. It leads to parts with high accuracy and narrow tolerances.

It is necessary to join AM components in many applications. There is a need for a reliable and versatile joining technique in prototyping when the final product is assembled, in the customiza-

▲ **Fig. 1** Welding of a snap clamping demonstrator part on the EvoWeld Mini table top machine (Source: Evosys Laser)

tion of injection molded mass products, or when the limited building space of a 3D printer is too small for the complete part [1]. The joining process should be versatile and practical for small quantities with often changing geometries because additive manufacturing is itself a tool-free and very flexible process. Laser plastic welding is a perfect match for this technique as it is a very versatile method, providing high quality weld seams.

Laser plastic welding is a standard process in the industry for many applications. In the most commonly used variant, laser transmission welding, a laser transparent part is joined with a laser absorbing one. In many cases, a diode laser with a wavelength of 980 nm is used. This wavelength is

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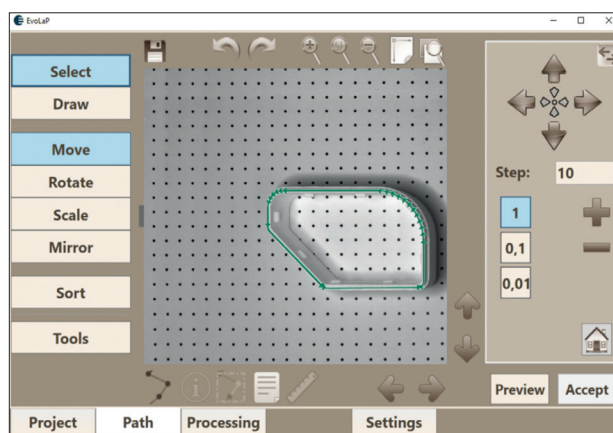


Fig. 2 EvoLaP scanner control software with a live picture of the working space as background (Source: Evosys Laser)

invisible to the human eye, so 'laser transparent' does not necessarily mean transparent for the human eye, making different color combinations possible. The laser transparent part (often a cover) is placed upon the laser absorbing one (often a housing). A clamping device is needed to ensure proper contact in the welding zone. The focused laser beam irradiates the welding zone, going through the transparent part, and is absorbed at the surface of the absorbing part, thus heating it up. Through heat transfer, the upper part warms up as well. Both joining parts plasticize in the boundary area and form the weld seam. Insufficient transmission of the upper joining part can lead to elongated weld times, decreased weld seam strength and material damage. If the transmission is too low, the parts are not weldable with this process variant.

Different process variants of laser transmission welding exist. The most common one is quasi-simultaneous welding in which a galvanometer scanner is used to move the laser beam along the contour of the weld seam multiple times at a high velocity. The weld seam is heated up quasi-simultaneously as a result of the high velocity. This quasi-simultaneous heating and plasticizing of the weld seam allows the upper joining part to move towards the lower one, leading to a better gap

bridging ability. The so-called welding collapse can be used for process surveillance or controlling. Another often employed variant is contour welding in which the laser irradiates the contour only once or a few times at a much lower speed. Mask welding and simultaneous welding are less used process variants because of their limited versatility and high system cost [2].

Solution for the challenging optical properties of AM parts

SLS parts are characterized by high accuracy, making them attractive for the industry, but also by a heterogeneous microstructure caused by the polymer powder. This microstructure leads to challenging optical properties such as decreased transmission and high scattering of the laser within the part. A method was developed to pre-treat the AM parts with a second laser to address this challenge. The second laser has a different wavelength than the welding laser and has higher absorption in the upper joining part. Using this pretreatment, it was possible to decrease surface roughness significantly and to increase transmission by over 50 %, leading to shorter weld times and a lower tendency to surface burns in comparison to untreated parts. Welding trials were carried out on parts with and without pretreatment of the surface, both leading to high quality weld seams.

Different material combinations tested

For testing purposes, PA12 demonstrator parts were manufactured both additively and by injection molding, enabling different material combinations to be investigated that are interesting for different application cases. IM-IM is the conventional combination and is used in many processes in the industry. It is used as a reference in the trials. AM-IM and IM-AM (depending on which joining part is the AM component) can be of use in the customization of mass products when mass-produced components are joined with individualized, small-series components. This combination and AM-AM are also useful for parts that are too big for the limited building chamber and therefore have to be built out of multiple parts. AM-AM is most interesting for prototyping and small series.

More flexible welding solutions

With the AM-AM combination, it is even possible to go one step further towards a tool-less welding process. It is necessary to apply a clamping force to ensure the heat transfer between both joining parts while welding, which is conventionally done by an outer or combined outer and inner clamping tool in combination with an elaborately designed workpiece carrier to be able to place the part with repeat accuracy.

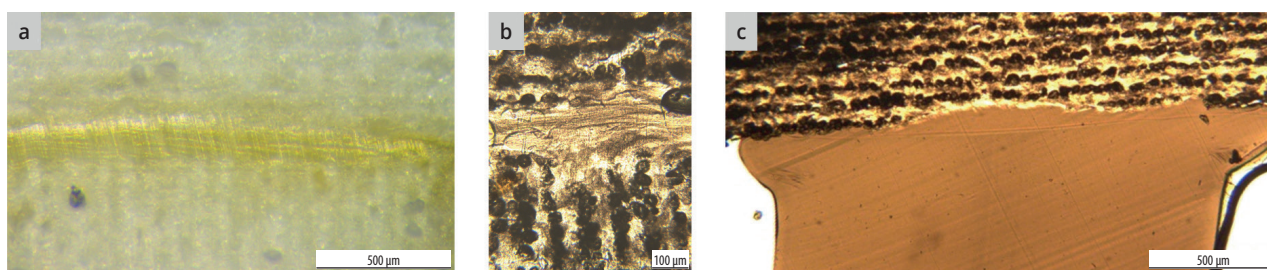


Fig. 3 (a) cross section of an AM-AM welding trial; (b) thin section of an AM-AM part; (c) cross section of AM-IM welding (Source: Bayerisches Laserzentrum, [3])

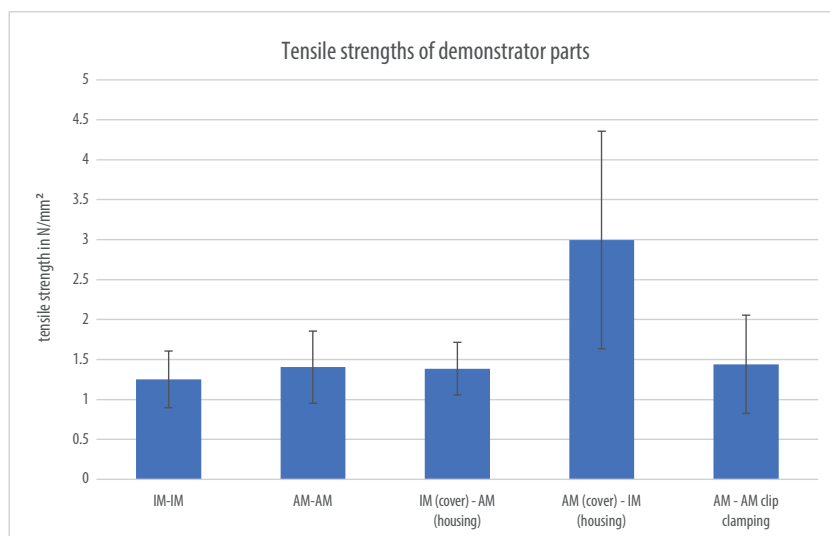


Fig. 4 Results of tensile strength tests with different material combinations (Source: Evosys Laser)

The clamping devices are manufactured using time-consuming and material-intensive machining processes, which is not always a good fit for welding additively manufactured components, especially for small quantities.

A more versatile process with tool-less clamping was developed to face this discrepancy and increase efficiency. By integrating clips along the perimeter of the additively manufactured parts, it is possible for the part to clamp itself without any external clamping devices. The newly-developed design, which can be seen in Fig. 1, ensures uniform and sufficient clamping pressure along the entire weld seam.

A camera system can be integrated into the machine to assist with the setup of the welding contour. Once fitted, a live picture of the working space can be seen in the background of EvoLaP, the company's own software for controlling the scanner and the scan contour. This enables the user to move the contour's vectors onto the welding bar of the part, as can be seen in Fig. 2. This is especially beneficial in prototyping where it allows the user to produce high quality weld seams right from the first part.

Investigations of the weld seam quality

All combinations were welded and the weld seam quality was investigated during the trials. Thin and cross sections of the weld seams were prepared and evaluated under a microscope to ensure an intact weld seam without cavities and defects. In Fig. 3, a cross section (a) and a thin section (b) of AM-AM combinations are shown. The remaining powder structure of the AM parts can be seen, which very clearly shows the melting and mixing of both

components in the weld zone without any defects. Fig. 3c shows a cross section of the IM-AM combination without cavities or defects in the weld seam.

In tensile strength tests, all the different combinations were tested as well as the tool-less clip clamping demonstrators. As can be seen in Fig. 4, all combinations reached very good tensile strengths, all comparable to or above the reference tensile strength of the IM-IM parts. It is noticeable that the AM-IM (cover-housing) combination has a higher tensile strength in comparison, but also a higher standard deviation.

With all configurations, tears occurred mostly not directly in the weld seam, but in either the cover or the welding bar, which indicates a very good weld seam.

Scalable solutions for every application case

The parts deployed in the welding trial showed sufficient transparency, so the preprocessing of the material with the second wavelength was not used. Nevertheless, the preprocessing can be of use and will be further investigated in the future. Depending on the application case, the process time reduction reached by the preprocessing might be useful, for example, when welding larger quantities of parts. In this case, a more complex machine with a two-wavelength module and a high grade of automation would be the best solution. The preprocessing with the second wavelength and the welding can be done with one machine and without additional handling of the part. Due to the special two-wavelength module, also used for Evosys' Advanced Quasi-Simultaneous Welding, both processing steps can even be done with

the same movement path of the laser, making the preprocessing no additional effort in the set up and handling of the part. In this application case, automated assembly and testing can also be integrated into the machine.

Another application case is the production of frequently changing parts in small quantities. Here the process time might not be a critical process variable as the welding time is negligible compared to the building time of the AM component. Consequently, the preprocessing might not be necessary and the cost for an additional laser source can be saved. A high automation level cannot be utilized as well, whereas an integrated camera system for easier set up of the contours for different parts would be very useful. A good solution for this application case would be a less complex machine with a smaller footprint and a low level of automation. Depending on the size of the parts, a table top machine could be used that can be set up in every laboratory, as can be seen in Fig. 1.

Conclusion

Tests were carried out to laser weld different combinations of AM and IM parts. PA12 components were additively manufactured as well as injection molded in order to investigate the weld seam quality and strength further. All combinations as well as the specially developed snap clamping method showed good results and high weld seam qualities. A method for pretreating the surface and thereby enhancing the transmission and weldability was developed for parts that show problematic low transmission of the laser transparent part. In order to be prepared for all customer requirements, further tests

will be carried out using other materials than PA12 as well as additional 3D printing techniques.

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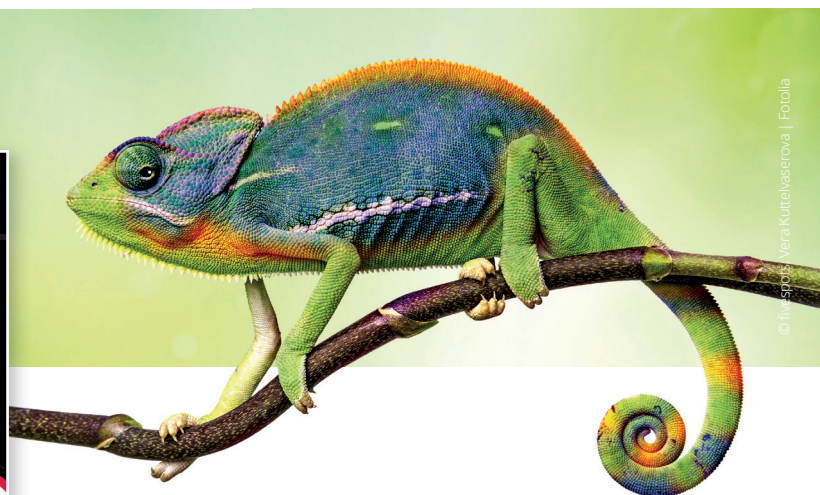
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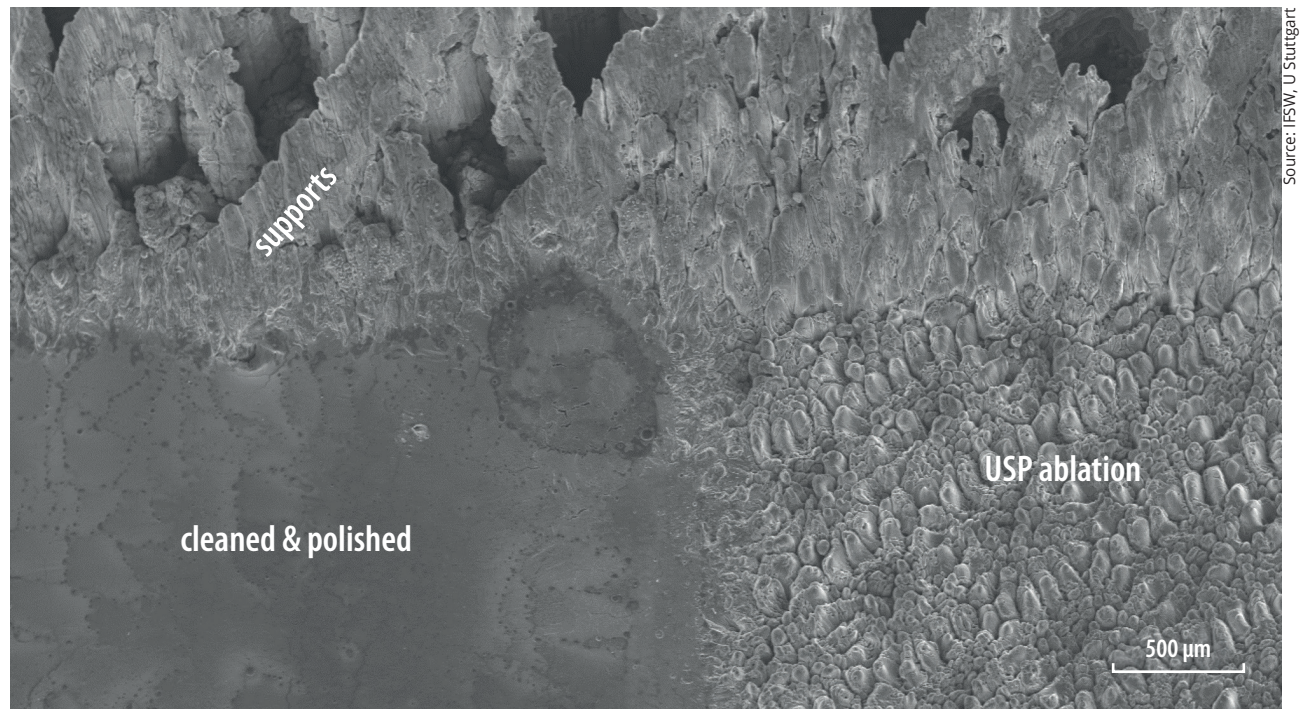
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Increasing productivity by combining laser processes

Laser-based postprocessing of additively manufactured metal parts

Markus Hofele & Matthias Buser



Increasing the material ablation rate in micromachining of precise geometries by ultrashort-pulsed laser treatment with high average power causes a decrease of achievable surface quality due to heat accumulation. To overcome this drawback, combined laser processes offer a significant increase of the overall productivity by the implementation of laser cleaning and polishing processes that require negligible additional processing time, but allow material removal to be performed with maximum process efficiency.

One of the biggest challenges in micro-machining with ultrafast lasers is to make use of the high average beam power provided by today's commercial ultrafast laser systems. Up to several hundred watts are already available in industrial systems [1]. To put this beam power into perspective, high-quality laser ablation on steel with a conventional galvanometer-scanner setup is typically limited to a few watts of average beam power.

One well-known approach to boost productivity within this constraint is to use high pulse repetition rates in combination with exceptionally fast

scan speeds. Systems with rotary beam deflecting elements reach scan speeds of several hundred meters per seconds [2]. However, this specialized technology lacks the flexibility in beam steering provided by a conventional galvanometer scanner. Polygon scanners are of no use for applications that require 3D surface treatment and processing of individual one-off parts, as is the case in the postprocessing of additively manufactured parts (PBF-LB). Furthermore, common beam shaping strategies creating a matrix of laser spots are not useable for selective controlled material removal.

▲ Combined laser post processing steps of PBF-LB parts for increased productivity: initial supports, removed supports by controlled USP laser ablation, final laser cleaned and laser polished surface

In this context, our work explores the combination of laser ablation with closed-loop control and laser cleaning and polishing steps to set up a high productivity processing chain that yields end-user ready surface quality [3]. The main idea is to accept quality deterioration during material removal with high power ultrashort laser pulses and to compensate for the unavoidable macroscopic surface roughening by closed-

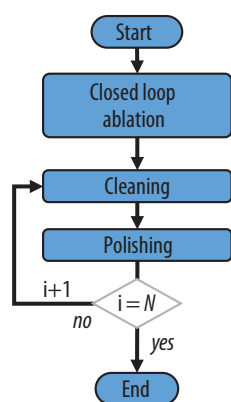


Fig. 1 Flow chart of the process chain. The minimal number of iterations i for this application was experimentally determined to $N = 3$ (Source: IFSW, U Stuttgart)

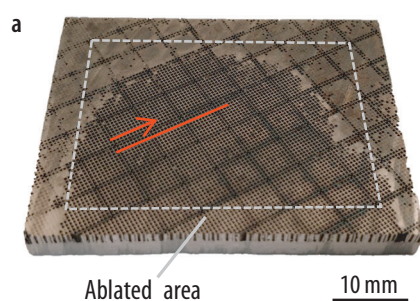
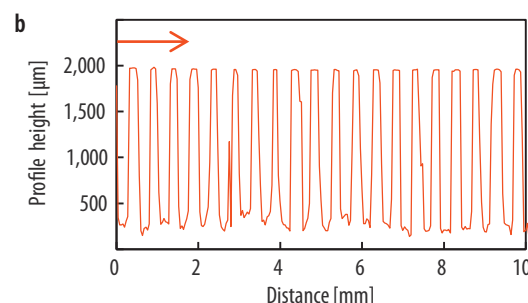


Fig. 2 (a) Picture of the down facing side of the L-PBF specimen after cutting from the constructed platform. The field for ablation is marked with dashed contour. (b) Residual support structure profile, measured by the OCT (Source: IFSW, U Stuttgart)



loop control. In subsequent process steps, the microscopic surface roughness is smoothed out by laser cleaning and laser polishing up to a glossy finish with submicrometer roughness. A material removal rate (MRR) of $21 \text{ mm}^3/\text{min}$ was achieved at 80 W beam power of the ultrafast laser and a final surface roughness after polishing of $R_a = 0.32 \text{ μm}$. All steps were demonstrated using near-infrared laser beams and galvanometer scanners, which paves the way for an all-in-one solution that provides this processing chain on a single machine.

Experimental methodology

Process chain

The main idea to achieve high MRR and good surface finish is to approach each goal with a separate laser process. The proposed process chain is depicted in Fig. 1. First, the support structures are removed using closed loop laser ablation in a high MRR process regime. Second, laser cleaning and polishing is performed iteratively to enhance surface quality. The required number of iterations N for good surface quality was determined during process development.

Ablation with closed control loop

The removal of the support structures is performed by using closed loop laser ablation. The closed control loop is required for precise selective removal of the supports and a form correction of the part. For the closed loop control, measuring was performed with an OCT sensor CHRocodile 2 from Precitec Optronik, which was coaxially superimposed to the processing beam. The OCT sensor was set up with

a measuring frequency of 70 kHz. The waist diameter of the OCT beam was measured to 69 μm on the surface of the sample. Independently of the beam diameter, the sensor provides an axial measuring accuracy of up to 1 μm . A self-developed software application was used for the closed loop process control. It is designed to trigger inline measurements of the process using the OCT sensor, to process and analyze the data, and automatically adjust the beam path during processing according to the difference between the set topography and the actual topography [4].

High MRR process regime

The process chain is based on the idea that the MRR of the ablation process can be maximized without any quality constraints. The subsequent cleaning and polishing are used to realize the desired surface characteristics. The maximum material removal rate achievable with the given setup was therefore experimentally determined on the L-PBF material. $3 \times 4 \text{ mm}^2$ sized pockets were produced on the sample using a conventional open loop process. This L-PBF specimen was ground flat before the treatment to enable the precise measurement of the ablation depth. The ablation volume was measured using a laser scanning microscope (LSM); cf. Fig. 3. The material removal rate is defined by $\text{MRR} = V_{\text{mat}} / t_{\text{emission}}$, where V_{mat} is the removed material volume. The time of emission t_{emission} is the accumulated time intervals of laser emission during the scans. Any unproductive times of jumps between scan lines are not considered. This MRR value is therefore independent of the specific ablation geometry or the properties of the scanner system.

A Carbide laser from Light Conversion was used, emitting at a wavelength of $1,030 \text{ nm}$ and with a pulse duration of 1 ps . At a maximum average beam power of 80 W , this system is able to emit pulse energies between 1.6 mJ (at 50 kHz) and 40 μJ (at 2 MHz). The optical setup consisted of a 2D galvanometer scanner with an f-theta lens of a focal distance of 340 mm , resulting in a spot diameter on the surface of 92 μm . The peak fluence was varied between 1.2 J/cm^2 and 48 J/cm^2 to determine the maximum MRR. The fluence was set by changing the pulse energy and pulse repetition rate while using the maximum average laser power of 80 W . The scan speed was constant at the maximum of 3 m/s . Scanning was performed at a hatching distance of 20 μm and an incrementally rotating scan orientation over 140 scans. The angle increment between each layer was set to 42° .

Fig. 3a shows the measured MRR over the peak fluence. The maximum $\text{MRR}_{\text{max}} = 21 \text{ mm}^3/\text{min}$ was achieved at a peak fluence of 3.2 J/cm^2 and a pulse repetition rate of 750 kHz . These parameters were used for the support structure removal. The SEM image in Fig. 3b shows the resulting surface of the machined pocket created at MRR_{max} . The presence of bumps is a typical result of heat accumulation [5], leading to a rugged surface. The structures with a lateral dimension of $70 - 100 \text{ μm}$ depicted in Fig. 3b exhibit a roughness $R_a = 30 \text{ μm}$ and $R_z = 147 \text{ μm}$.

Laser cleaning

Laser cleaning was applied as a subsequent step to remove debris and residual ablation material out of the ablated surface structure. The laser cleaning was performed with a short pulse fiber

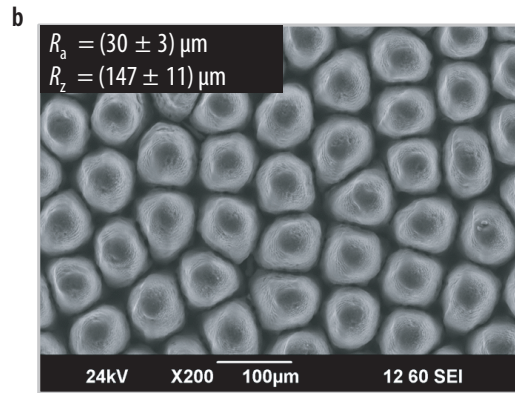
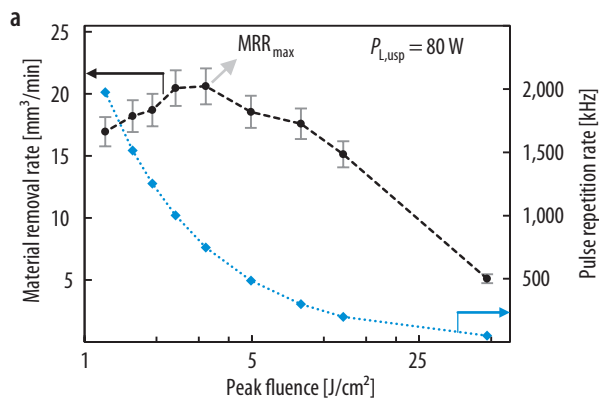


Fig. 3 (a) Measured MRR of the USP ablation process on AlSi10Mg material at the maximum laser power of 80 W and variable peak fluences between 1.2 J/cm² and 48 J/cm² (b) SEM image of resulting surface structures treated at MRR_{max} (Source: IFSW, U Stuttgart)

laser TruMark 5020 from Trumpf with a wavelength of 1,062 nm and a pulse duration of 70 ns at a pulse frequency of 65.5 kHz. The laser process was performed with a 2D scanner and a defocused laser beam of 122 μm in order to reduce the beam fluence. The cleaning was carried out at a scanning speed of 3 m/s and track offset of 70 μm over three scans, resulting in a total area rate of 42 cm²/min. These settings have proven to be effective for debris removal on additive manufactured AlSi10Mg [6].

Laser polishing

A TruDisk 4002 Yb-disk laser from Trumpf with a wavelength of 1,030 nm was used for laser polishing, which was operated in the pulse mode with a pulse duration of 0.3 ms, pulse power of 1.7 kW, and a pulse repetition rate of 1 kHz. An I-PFO 3D scanner optics by Trumpf with a defocused beam diameter of 1,050 μm was used. The treated area was scanned in linear hatchings with a line spacing of 50 μm at a scanning speed of 200 mm/s, resulting in a pulse overlap of 81.0 %, a track overlap of 95.2 % and an area rate of 6 cm²/min. These parameters were found to be optimal for vertical printed L-PBF AlSi10Mg surfaces [7]. The process was performed in a sealed chamber under a purified Argon gas atmosphere to protect the samples from any nega-

tive influences of atmospheric oxygen during the polishing.

Material sample

The AlSi10Mg specimens were built by PBF-LB on a TruPrint 1000 from Trumpf with a slicing thickness of 20 μm. The layers were generated with a laser power of 175 W and scanning speed of 1,400 mm/s. The lattice support structure with a ridge with of 0.2 mm and a spacing of 0.5 mm was produced with laser power of 150 W and a scanning speed of 2,000 mm/s. For the experimental investigations, two rectangular plates with 3 mm thickness were built up for the parameter study and the demonstration of the process chain. The parts were cut from the platform by a water-cooled saw. Fig. 2 shows the residual support structure on the sample with a height of 2 mm. To determine the ablated volume of the support structures, the sample's mass was measured before and after the ablation process with a precision scale I 2000 D by Sartorius, and the ablated volume was calculated using the density of 2.67 g/cm³ provided by manufacturer Heraeus.

The demonstration of the process chain was conducted on a rectangular test area (Fig. 2 dashed line, 40 × 30 mm²) within the residual support structure of the specimen plate (50 × 40 mm², Fig. 2). The ablation geometry

is designed as a pocket with a depth of 2.2 mm in order to ensure removal of all support structures and the porous initial layer of the print. The side walls of the pocket are designed with draft at an inside corner angle α of 114° to prevent edge deepening.

Results

Closed loop ablation

The state of the sample after ablation is shown in Fig. 4. The ablation process with closed loop control took in total 184 minutes to remove 1,592 mm³ of material. Thereby, it successfully removed all the support structures within the specified field (a). As to be expected from the chosen processing parameters, the surface appears dark, indicating residual debris and severe roughness (b). However, all the support structures are removed, leaving a flat surface as evidenced by the cross sectional height profile (c). The resulting surface exhibits a roughness of $R_a = 24 \mu\text{m}$ and $R_z = 148 \mu\text{m}$.

Examining the topography section measured with LSM (b), it reveals that the microstructures still indicate the former presence of the ridges. Coarser bumps have formed in those areas where more material was removed. The average roughness $R_a = 24 \mu\text{m}$ is in the range of the roughness $R_a = 30 \mu\text{m}$ measured in the parameter

Institutes

LaserApplikationsZentrum (LAZ)

The Laser Application Center (LAZ) at Aalen University of Applied Science is doing research in a wide field of laser material processing for industrial manufacturing applications. The institute is equipped with modern labs and machines with multi-kW cw laser sources up to high precision ultra-short-pulse machining in the IR, VIS and UV range. The team of scientists and engineers works on fundamental projects as well as on interdisciplinary projects with industrial partners.

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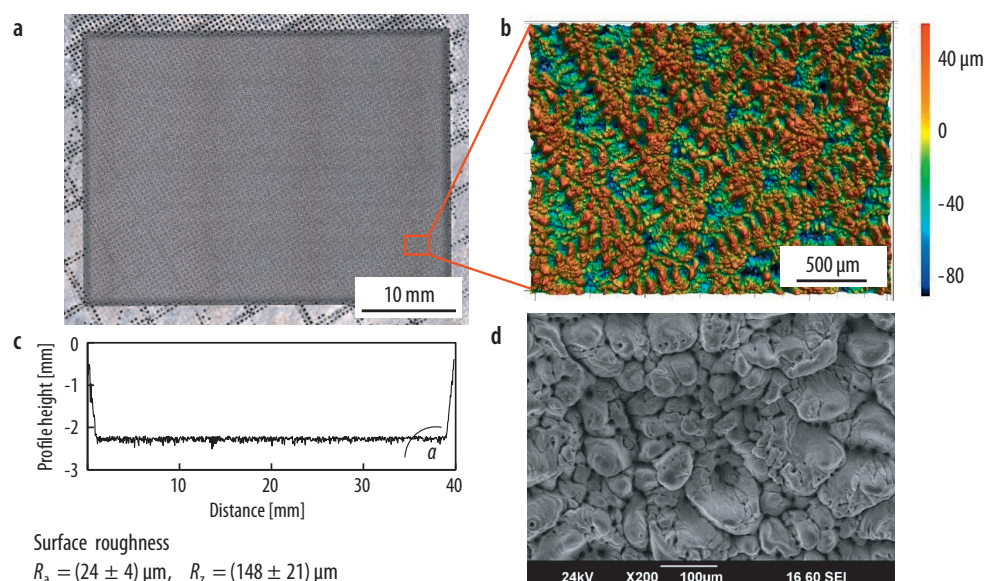


Fig. 4 Resultant surface after closed loop ablation. (a) Light microscope image of the 40×30 mm ablation field. (b) Laser scanning microscope image of a subsection topography. (c) Cross section of the surface after ablation, including the slopes with a corner angle α of 114° and measured roughness values. (d) SEM image of the created surface structures (Source: HS Aalen)

study for the applied processing parameters (Fig. 2). The total processing time of 184 minutes includes the accumulated time of emission corresponding to the MRR_{max} of $21 \text{ mm}^3/\text{min}$ and all unproductive down times such as intermediate measuring with the OCT and scanner jumping vectors, leading to an overall MRR of $8.65 \text{ mm}^3/\text{min}$.

Cleaning and polishing

Fig. 5 shows a light microscope (LM) and a scanning electron microscope (SEM) image of a subsection of the sample before and after cleaning. The cleaned surface appears brighter in the LM image (a) which indicates that less particles such as oxides, smudge and ablation residuals are present on the surface. The surface structure in the cleaned area is not changed compared to the uncleaned surface as shown by the SEM image (b), hence the process did not remove any bulk material. The positive impact on the appearance becomes clear after polishing.

Fig. 6 shows LM images of the polished area after each of the three clean-

ing and polishing iterations according to the flow chart in Fig. 1. The image of the first iteration shows dark discoloration due to impurities from the ablation process trapped in the surface structure that were deposited on the surface during remelting. It can be assumed that the initial cleaning step insufficiently eliminated the debris due to the profound surface structures remaining after laser ablation, see Fig. 2. Additionally, some porosity remained on one side of the area. A second and third iteration of cleaning and polishing was therefore performed. With each step, the amount of smudge deposition and superficial porosity progressively diminished. After the third iteration, a shiny surface containing few isolated pores is created. The form deviation within a measuring area of 2 mm amounts to only a few microns, Fig. 6. The SEM image shows that the surface is almost free of microstructures, leading to a roughness of $R_a = 0.32 \mu\text{m}$ and $R_z = 2.2 \mu\text{m}$.

The three iterations took 0.7 minutes for laser cleaning and 4.5 minutes

for laser polishing. Together they only contributed an additional 2.8 % to the overall processing time.

Conclusion and outlook

This study addresses the question of whether it is possible to achieve a surface quality with sub- μm roughness using a high productivity laser-based processing chain on an arbitrary geometry of high roughness and shape deviations. One application is support structure removal on parts made from laser powder bed fusion. The procedure investigated consists of closed loop laser volume ablation and subsequent laser cleaning and polishing steps, shown in the teaser image. We improve productivity during ablation at the expense of surface quality and restore the finish in subsequent cleaning and polishing steps. The results show that an ultrashort-pulse laser operating at an average laser power of 80 W enables a maximum material removal rate of up to $21 \text{ mm}^3/\text{min}$. The selective OCT-controlled ablation of the supports of this exemplary

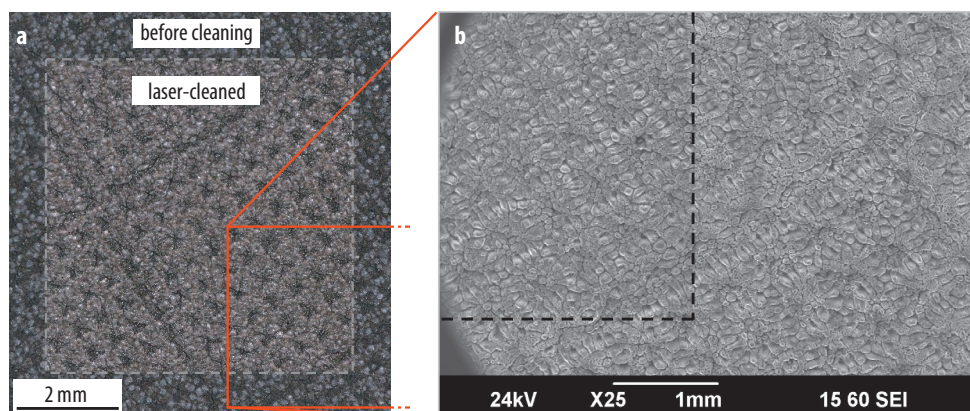


Fig. 5 (a) Light microscope image of a cleaned area within the ablated surface. (b) Scanning electron microscope image of clean and unclean surface (Source: HS Aalen)

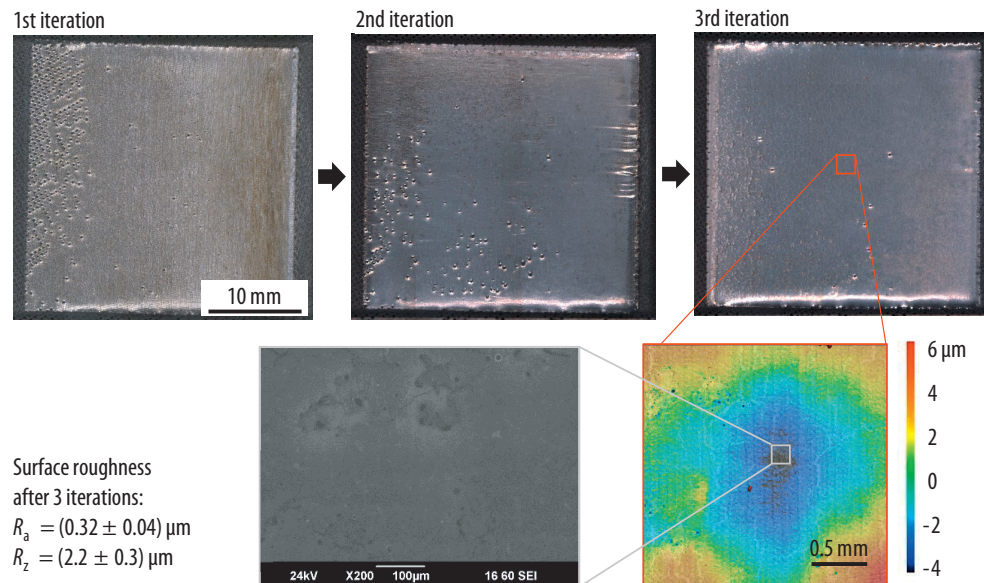


Fig. 6 Resultant surface quality with one, two and three iterations of cleaning and polishing. Final surface quality and roughness shown by LSM and SEM images (Source: HS Aalen)

application makes an effective average ablation rate of $8.65 \text{ mm}^3/\text{min}$ achievable. The additional cleaning and polishing process in a sequence of three cycles took only a negligible 2.8 % additional process time of the complete treatment, but enables an excellent glossy surface quality with a roughness improvement from the ablation stage by two orders of magnitude from $R_a = 24 \text{ µm}$ down to $R_a = 0.32 \text{ µm}$ ($R_z = 148 \text{ µm}$ to 2.2 µm).

The process strategy presented here will be crucial in future to implement this strategy in one machine and process, as lasers with the temporal degrees of freedom to emit pulses and switching from ultrashort pulses to continuous waves become commercially available. Additionally, further refining the process strategy through iterative cyclic switching between those processing steps can lead to additional improvements. Small shape deviations caused by polishing cycles can be corrected again using closed-loop ablation. Furthermore, achieving a very smooth finish by integrating polishing with bursts of ultrashort pulses at gigahertz frequencies within a single burst package can enhance the process strategy even more.

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is the head of the macro laser application team at the LAZ. He received his doctor degree in 2023 from the Glasgow Caledonian University for his research on the topic of laser-based post processing of L-PBF aluminum parts. During more than one decade of research, he has acquired experience in a wide field of laser applications such as welding, brazing, heat treatment, surface structuring and cleaning, as well as laser polishing.



Matthias Buser

received his MSc degree in mechanical engineering from the University of Stuttgart in 2017. He joined the Institut für Strahlwerkzeuge IFSW at the University of Stuttgart as a research associate, where he is part of the department for system engineering. His work is focused on closed-loop control in laser micromachining, optical sensor technology, and the combination of additive and subtractive laser-based processes as part of the Innovation Campus Mobility of the Future.



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Tracking greenhouse gases with a laser

Fraunhofer ILT researchers develop advanced lidar systems to tackle global methane emissions and improve climate monitoring



Source: Fraunhofer ILT

Faced with advancing climate change, we drastically need to monitor and understand the various sources and sinks of greenhouse gases worldwide in real time. One approach to accomplishing this is to regulate and monitor man-made methane emissions. Laser systems as developed by researchers at Fraunhofer ILT offer ways to do exactly that. At the heart of lidar instruments, they can precisely determine greenhouse gases in the atmosphere with high spatial and temporal resolution, even from great distances, and do so worldwide.

The summer of 2023 was by far the hottest since we began keeping records. It was probably even the hottest summer for around 120,000 years. This global warming is caused by the gas emissions in the atmosphere, mainly those of methane and carbon dioxide. As a greenhouse gas, methane is more than 25 times more active than carbon dioxide. Furthermore, the concentrations of methane, compared to those in the pre-industrial age, have increased even more than those of carbon dioxide. Methane, however, also decomposes more quickly in the atmosphere, meaning that methane reduc-

tions have a short-term positive effect on the climate.

Although it is largely known how methane enters the atmosphere, it is

▲ The experts at Fraunhofer ILT have spent years perfecting the assembly of laser systems for use in the aerospace industry

Institute

Fraunhofer Institute for Laser Technology ILT

With over 480 employees and more than 40 spin-offs, the Fraunhofer Institute for Laser Technology ILT in Aachen is one of the leading contract research and development institutes in its field. For more than 35 years, the Fraunhofer ILT experts have been developing and optimizing laser beam sources and laser processes for production and metrology, energy and mobility, medical and environmental technology, as well as quantum technology.

www.ilt.fraunhofer.de



Source: Photo Fluxys Belgium - David Samyn

The helicopter with the lidar system has already flown many thousand kilometers and checked pipes for leaks

usually unclear where and when this happens and to what extent. Does it come from the tundra or from leaking gas pipelines, from cattle farms or the methane hydrate thawing in the sediment layers of the oceans?

The uncontrolled emission of methane during the extraction, production, transportation or processing of fossil fuels accounts for eleven percent of greenhouse gas emissions worldwide, according to the German Association of Energy and Water Industries. Eighty percent of methane emissions, on the other hand, can be attributed to agriculture and waste management. According to the International Energy Agency (IEA), 1.7 percent of the gas produced worldwide is lost through leaks. The Energy Watch Group calculates this at over four percent, while other experts provide even higher figures.

It is therefore important to precisely record and monitor the concentration of greenhouse gases in the atmosphere. Until now, methane has only been measured passively from space, i.e. via the sunlight absorbed in the atmosphere by this gas. The concentration can then be calculated from the

absorption. However, this method only works during the day and its accuracy is limited.

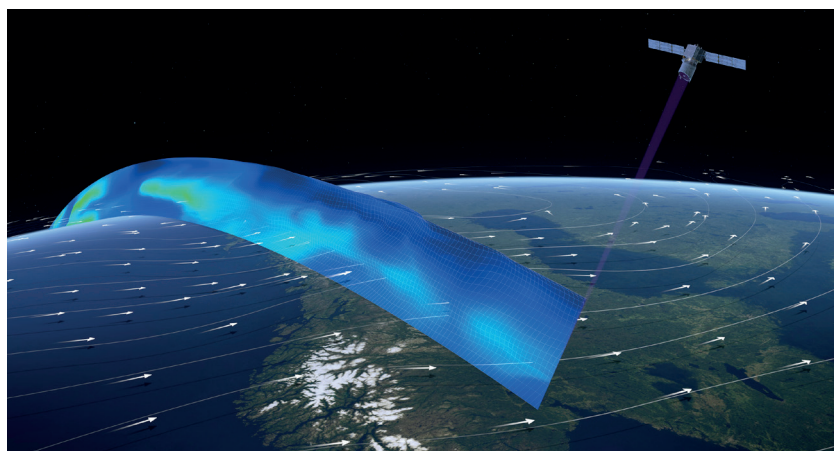
A light detection and ranging (lidar) system, however, can determine the methane concentration directly. This uses lasers with two wavelengths at around 1,645 nm to make the measurement independent of external factors such as the strongly fluctuating reflectivity of the earth's surface. It measures the light absorption of the atmosphere at wavelengths of maximum and minimum methane absorption. The methane concentration in the air column in the measurement path is calculated by comparing the measured values.

Lidar measurement from a helicopter

Lidar technology is a well-established method to investigate and determine local methane concentrations emitted from pipelines: natural gas consists of around 85 percent methane. Every leak that occurs during exploration or transportation is a source of methane that is not only harmful to the climate but also poses an acute risk of explosion, which is why operators check pipelines, com-

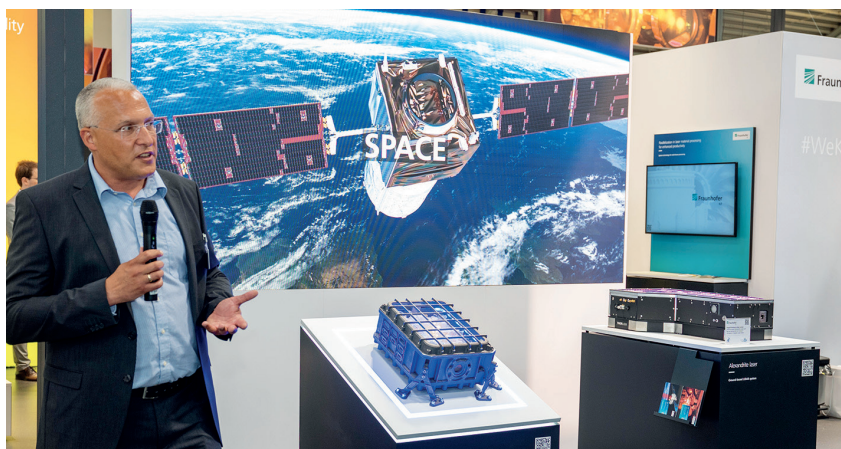
pressor stations and other facilities for methane leaks. The Adlares company from Teltow near Berlin has implemented the CHARM (CH_4 Airborne Remote Monitoring) process for this purpose, which can measure methane concentrations from a helicopter as it flies over the pipelines. The helicopter flies at speeds of up to 180 km/h at an altitude of 100 to 150 meters and, thanks to its high measuring rate of 1,000 measuring points per second, can register leakage rates of 150 l/h at wind speeds of up to 24 km/h. The beam source for the lidar system was developed by a team at the Fraunhofer Institute for Laser Technology ILT in Aachen. The second generation CHARM system contains two diode-pumped Nd:YAG lasers with a particularly narrow line width. Adlares supplied an optical parametric oscillator that converts the wavelength of the laser from around 1 μm to the mid-infrared at 3.3 μm .

In the meantime, the helicopter has not only flown along many thousand kilometers of pipelines with the lidar system, but has also examined emissions from landfills, wastewater treatment plants, coal mines and farms. The



Source: ESA / ATG Medialab

The successor to the ADM Aeolus satellite will use a powerful UV-lidar to measure wind profiles over the earth in detail



Source: Markus Jürgens / Fraunhofer ILT

Project manager Bastian Gronloh explained the details of the Aachen laser technology for satellite applications at the Laser World of Photonics 2023

system is so sensitive that it can even measure the emissions of a single cow.

Mapping the earth's atmosphere from a satellite

Individual facilities can be checked quickly by helicopter, but this method is too expensive and slow to search for methane sources globally. When permafrost thaws, for example, it can emit methane in low concentrations over huge areas. This is why the German and French space agencies planned the Methane Remote Sensing Lidar Mission (MERLIN) several years ago. A satellite will measure and map the methane concentration in the earth's atmosphere from an altitude of around 500 kilometers. On board the satellite will be a lidar instrument with a laser beam source from Fraunhofer ILT in Aachen.

The components of the lidar instrument of the MERLIN mission were designed and developed by a consortium of German industrial companies and research institutes. Scientific responsibility lies with the lidar department of the DLR Institute of Atmospheric Physics (IPA) in Oberpfaffenhofen, Germany.

Fraunhofer ILT has been developing technology for space-qualified laser systems for partners such as the German Aerospace Center DLR, Airbus Defence and Space, Tesat Spacecom and the European Space Agency ESA for many

years. The Aachen-based institute has built the complete manufacturing technology for this purpose. Components manufactured in this way can withstand the stresses and strains of launch and operation in space.

The laser at the core of the lidar system must be able to withstand shocks of up to 300 g and vibrations of up to 25 g, as well as alternating thermal loads from -30 °C to +50 °C. The developers also have to avoid organic materials such as adhesives as far as possible so as not to contaminate the high-purity mirror surfaces. And of course, the laser must function maintenance-free and without degradation for the duration of the mission of more than three years.

The next mission: wind lidar

The team is preparing a tender for the next phase of the Aeolus-2 satellite using a laser platform similar to the MERLIN project that is currently being built at Fraunhofer ILT. This will use a Doppler lidar system to measure wind speed and direction in the atmosphere. Following the success of the first Aeolus mission, even higher-resolution wind data will help to improve global weather models. Together with Airbus Defence and Space, Fraunhofer ILT is currently building the laser for the engineering model of the Aeolus 2 mission. It is a frequency-tripled Nd:YAG laser that delivers an output energy of 150 mJ at 355 nm. This laser system is based

on the space-qualified technology that has been tried and tested for years and which also contributes to the success of MERLIN.

ESA considers lidar systems to be an important future technology with great potential for the further development of global weather models. Firstly, they can significantly improve weather forecasting, with particular importance for disaster management. As weather extremes caused by climate change increase, so does the need for early warning and rapid action.

Secondly, as renewable energies expand, the need for accurate forecasts for local wind conditions and hours of sunshine increases. The higher the proportion of volatile power sources, the more important it becomes to carefully manage and control the grid infrastructure. In this way, lidar systems and research at Fraunhofer ILT are supporting Europe on its way to achieving net-zero emissions by 2050.

Fraunhofer Institute for Laser Technology ILT

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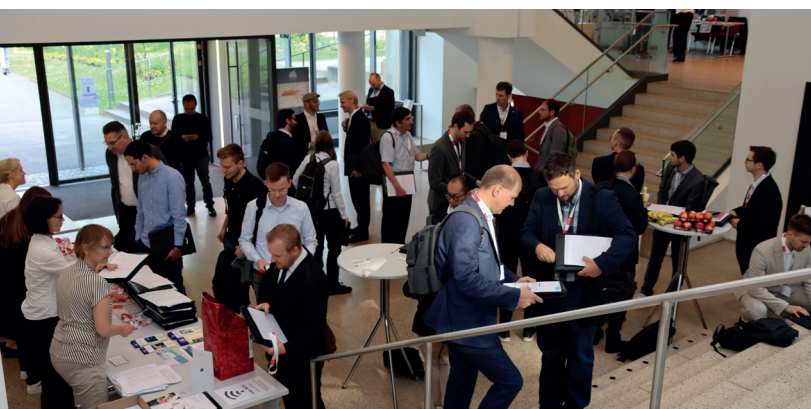


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Source: P E Schall



Source: Monika Gaul, IFSW U Stuttgart

September 11 – 13, 2024

EOSAM 2024

Naples, Italy

www.europeanoptics.org



October 08 – 09, 2024

Quantum Effects

Stuttgart, Germany

www.quantum-effects.com



September 11 – 13, 2024

CIOE

Shenzhen, China

<https://cioe.cn>



October 15 – 19, 2024

29. Fakuma

Friedrichshafen, Germany

www.fakuma-messe.de

September 15 – 19, 2024

13th CIRP Conference on Photonic Technologies [LANE 2024]

Fuerth, Germany

www.lane-conference.org



October 15 – 16, 2024

**6th Conference on Laser Polishing LaP
1st Conference on Laser-based Optics Manufacturing LOM**

Aachen, Germany

www.ilt.fraunhofer.de/de/messen-und-veranstaltungen

September 23 – 25, 2024

ECOC2024

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www.ecocexhibition.com



October 22 – 25, 2024

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Hanover, Germany

www.euroblech.com

September 24 – 27, 2024

Micronora

Besançon, France

<https://micronora.com>

September 25 – 26, 2024

W3+ FAIR

Jena, Germany

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



October 30 – 31, 2024

SPIE Photonex 2024

Manchester, United Kingdom

<https://spie.org/conferences-and-exhibitions/photonex>

October 08 – 10, 2024

VISION

Stuttgart, Germany

www.vision-messe.de



November 06 – 07, 2024

14th Jena Laser Conference

Jena, Germany

<https://lasertagung-jena.de>



November 27 – 28, 2024

13. Laser Anwender Forum | LAF 2024

Bremen, Germany

www.bias.de/LAF



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

“Inspiring, highly specialized, and international”

Review: 16th Optatec, 14 – 16 May 2024, Frankfurt, Germany

The industry highlight at its traditional venue in Frankfurt focused on an exciting topic, namely the technical exploitation of light. 422 exhibitors from 24 countries showcased innovations from the fields of optotechnology, optical metrology, new technologies, sustainable manufacturing processes and modern machines on 18,000 square meters of exhibition floor space. Roughly 64 % of the exhibitors came from outside of Germany. A total of 3,962 expert visitors attended.

Optatec 2024 was once again able to confirm its world-leading status and was also distinguished by an impressive supplementary program: seminars were

held by the Spectaris photonics association, a CEO Roundtable dealt with “The photonics and optics industry in times of uncertain markets”, the technology park for “Education and Research – Studying Photonics” provided information on photonics masters programs offered in Hesse and, as a communication platform geared towards expert visitors, the exhibitor forum provided additional information about participating companies and technologies.

Bettina Schall, managing director of trade fair promoter PE Schall, said: “Optatec is the industry meeting place par excellence, and we look forward to seeing you again at the 17th Optatec,



Source: PE Schall

Impression from Optatec 2024

two years down the road, in Frankfurt from the 5 – 7 May 2026.”

www.optatec-messe.de

“Bringing together what belongs together”

Review: RapidTech 3D, 14 – 16 May 2024, Erfurt, Germany

Marking its 20th anniversary, RapidTech 3D has impressively reaffirmed its reputation as a pioneering trade event for industrial 3D printing. Once again, 2,700 visitors from Germany and abroad came to learn about and compare notes on the latest applications, developments and trends in the field.



Impression from RapidTech 3D, 2024

This year's event was for the first time sponsored by the VDMA (German mechanical and plant engineering association) additive manufacturing working group.

The four keynote speeches at the high-caliber specialist conference, along with some 70 presentations, almost 100 exhibitor presentations in the hall and intensive networking formats, showed that additive manufacturing (AM) has a firm foothold in series production and that developments in both materials and technology are constantly expanding its applications. This is true both of established AM user industries such as aerospace, medical technology and automotive and of industries where

AM is still a relatively new technology, such as microelectronics, chemicals and mechanical engineering.

The first-ever AM4industry forum focused on AM applications for and within mechanical engineering and included contributions from Reintjes, DiManEx, Toolcraft, Hermle, Siemens and Trumpf. The forum was initiated and hosted by VDMA.

Other industry and subject forums included Aerospace, Innovations in AM, Software, AI & Design as well as AM Science and AM Science by Fraunhofer.

The next RapidTech 3D will be held in Erfurt from 13 – 15 May 2025.

www.rapidtech-3d.de

SLT's premiere at downtown Stuttgart

Review: Stuttgart Laser Technology Forum, 4 – 6 June 2024, Stuttgart, Germany

The 12th Stuttgart Laser Technology Forum (SLT 2024) took place in the Kursaal Stuttgart-Bad Cannstatt for the first time. The conference brought together around two hundred experts from all over the world to discuss the latest developments and applications in laser technology. The event offered a wide range of presentations and discussions on various laser technology topics.

Both current research results and industrial applications were presented. The focus was particularly on topics such as artificial intelligence in production and advances in quantum technology.

Over the three days of the conference, numerous renowned speakers presented their work and findings, including the following plenary speakers:

- Jens Anders from the Institute for Intelligent Sensors, University of Stuttgart, spoke about the miniaturization and industrialization of quantum sensors
- Michael Förtsch from Qant, Stuttgart, spoke about photonic quantum technologies
- Benno Willke from the Max Planck Institute for Gravitational Physics

and Leibniz Universität Hannover presented highly stabilized lasers for the search for gravitational waves and dark matter

- Eric Mottay from Amplitude, Pessac, France, and H-Nu, Bordeaux, France, discussed high-power laser processing with kilowatt femtosecond lasers
- Andreas Michalowski from the IFSW at the University of Stuttgart spoke about AI-supported flexible laser production
- Christian Daniel from Robert Bosch, Renningen, presented the industrial applications of AI at Bosch.

Two parallel sessions were held during the conference, covering different aspects of laser technology:

- Laser sources and beam shaping
- Laser processing for e-mobility
- Fiber optic beam delivery
- Laser processing for quantum technologies
- Machine learning in manufacturing
- Additive manufacturing and micro-machining

Nine conference contributions were



Industrial presentation at SLT 2024 (Source: Monika Graul, IFSW U Stuttgart)

submitted by the presenters for a special section of PhotonicsViews issue June/July/August 2024.

The social program included a visit to the Gottlieb Daimler Memorial and a conference dinner in the 'Kleiner Kursaal'. There was also a guided tour of the IFSW laboratories on the Vaihingen campus of the University of Stuttgart.

The SLT 2024 was once again an excellent platform for dialogue and net-

working among the participants. The research results and innovations presented showed the dynamic development of laser technology and its importance for various branches of industry. The organizers thank all participants and speakers for their valuable contributions and are already looking forward to the next edition of the Stuttgart Laser Technology Forum.

www.slt.uni-stuttgart.de

Global experts gather to advance laser-based manufacturing for e-mobility

Review: LaserEMobility Workshop 2024, 17 – 18 July 2024, Garching near Munich, Germany



Presentation in the industry session

The LaserEMobility Workshop 2024, an international event of innovation in the e-mobility sector, marks a milestone in its journey advancing laser processes. LaserEMobility was established in 2020 as a section of the Italian Manufacturing Association (AITeM). Its main event, the LaserEMobility Workshop, is a collaborative event organized by the University of Bologna, Politecnico di Milano and the Technical University of Munich. After the University of Bologna inaugurated the first edition in

2022 and Politecnico di Milano hosted the second in 2023, this year's awaited event took place at TUM. The event, which is dedicated to research, development and collaborative activities in relation to advanced laser processes in e-mobility, highlighted the growing interest of an international community.

Approximately 200 registration requests, supported by 20 sponsors from leading companies in the laser-based manufacturing industry enabled a two-day workshop for 157 participants, making the event a center for cutting-edge innovation and knowledge sharing. The program included 22 industry presentations, showcasing the advancements in practical applications, alongside 16 academic presentations that delved into the latest insights of research. Additionally, a poster session was present for the attendees, offering a platform for discussions.

Overall, the environment fostered a vibrant exchange of ideas between leading industry representatives and

academic experts, highlighting the commitment to driving the further development of electromobility through laser technologies. The presentations addressed application-oriented topics over the whole field of laser-material processing for electromobility, including battery systems, electric drivetrain, fuel cells, lightweight construction, process modelling, and diagnostics for e-mobility applications.

While laser welding applications remained a focal point, laser cutting, structuring and additive manufacturing in the field of electromobility also received increased attention. Beam shaping across space and time, as well as different laser wavelengths, were presented to the audience, emphasizing the possibility to handle more complex material systems with heightened productivity demands.

To ensure efficient material utilization and high-quality standards, many industrial companies have focused on the integration of inline monitoring

solutions. Furthermore, methodological studies, modelling and simulations were a central topic, determining the optimal beam-material combinations. The LaserEMobility Workshop played a key role in gathering professionals and researchers to showcase and openly discuss technologies, as clearly demonstrated at this year's event.

Overall, the event drew speakers from seven different countries. Numerous presenting companies emphasized the industry's demand for skilled professionals, highlighting the significance of networking events like the Laser-

EMobility Workshop for the exchange of ideas and the transfer of knowledge as well as the transition of new concepts and professionals from academia to industry. With attendees coming from 16 different countries, the organized event successfully facilitated an international exchange of expertise. The time set aside for breaks throughout the event allowed participants to visit exhibition booths and explore the latest trends in laser system technology. Additionally, this time provided opportunities for networking and discussions on the presented scientific and technical results.

With the conclusion of the LaserEMobility Workshop 2024, the engaged audience is already anticipating the next edition in the year 2025. The workshop will continue to serve as an important platform where industry experts, researchers, and innovators come together to share insights, discuss advancements, and shape the future of electric mobility together.

The workshop program and the abstract book can be accessed following the link LaserEMobility Workshop.

<https://laseremobility.com>

Preview: LANE 2024

15 – 19 September 2024, Fürth, Germany

Organized by the Bayerisches Laserzentrum BLZ and the Institute of Photonic Technologies IPT of the Friedrich Alexander University Erlangen-Nürnberg, the 13th CIRP Conference on Photonic Technologies [LANE 2024] has its focus on the exchange of up-to-date scientific results and developments on the application of lasers in research and production.

Providing an international platform for participants from both science and industry, all relevant topics of laser material processing will be presented and discussed in about 200 talks – including top-class keynote talks and

inspiring invited presentations – at LANE 2024.

Next to additive manufacturing, laser beam welding, precision processing with short and ultrashort pulses, sensing and control or surface treatment and forming, emerging technologies and hot topics as artificial intelligence (AI) and machine learning, fast beam manipulation and beam shaping, material processing in the visible wavelength range and Industry 4.0 and digitalization will be covered by the conference program.

Special sessions on laser processes for future mobility, manufacturing in

space, solidification cracks during laser

beam welding and a country special “Laser Technology in Singapore” complete the agenda.

An accompanying exhibition during all conference days offers companies perfect opportunities to present their innovative products and services to an international audience of experts. The exhibition booths, that will be located in the coffee and lunch break area of the conference venue, strengthen the link between research work and industrial application.

www.lane-conference.org



Preview: W3+ Fair Jena

25 – 26 September 2024, Jena, Germany

The W3+ Fair, which will open its doors for the second time in Jena, Thuringia, aims to pave the way for them. After last year's successful premiere, the trade fair for photonics, optics, electronics and mechanics is returning to the Sparkassen-Arena Jena. With more than fifty new exhibitors and two fully booked halls, the trade fair continues its success story and underlines its importance as the leading event for innovations in Central Germany. Trade visitors will find the latest technologies, talents and up-to-date knowledge transfer across industry boundaries. Big names such as Zeiss, Jenoptik and Schott will be represented, as will

numerous hidden champions that are world-renowned in the industry. The organizers – Fleet Events together with OptoNet eV from Jena – are expecting over 2,000 visitors.

With more than 200 exhibitors and partners, this year's fair will be larger and more diverse than last year. The Thuringian joint stand will be represented with 25 booths. Nucleus – a joint initiative of the Ernst Abbe University of Applied Sciences Jena and the Friedrich Schiller University Jena – will be presenting the latest results of university research at the Campus Area.

Over half of the exhibitors are from outside the region or come from

abroad. In total, companies from eleven countries will be exhibiting, including companies from Switzerland, the Netherlands, Lithuania, and the USA. This shows the importance of the region for key technologies.

A highlight of the trade fair is the free accompanying conference “en-tech. talks”, which takes place parallel to the exhibition and guarantees up-to-date knowledge transfer.

The W3+ Fair is supported by numerous trade associations and regional partners, above all the gold partners OptoNet and the photonics industry network EPIC.

<https://w3-fair.com/en/jena>



Preview: Quantum Effects

8 – 9 October 2024, Stuttgart, Germany

After exceeding expectations at its premiere in 2023, Quantum Effects is now considered the leading trade fair and conference for application-oriented quantum technologies with an annual cycle. Here, world market leaders and application industries are promoting international cooperation and strengthening Europe's sovereignty in the global quantum landscape.

Quantum Effects is enthusiastic about quantum technologies and offers an ideal platform for innovation, inspiration and collaboration. Together with industry, science, politics as well as relevant networks and investors, a comprehensive quantum ecosystem is being developed and designed.

The figures of last year's event include 2,337 participants, 75 exhibitors from eight countries and 95 lectures on three stages. 76 % of visitors are decision-makers or involved in investment decisions.

The supporting program has been expanded to include exciting formats. Start-ups present their innovative ideas in short format at the new Start-up Investment Pitches. The Female FutureTech Summit is a women's network meeting that supports the exchange and promotion of female talent in the tech world. The HPC Quantum AI Conference offers lectures by national and international speakers on the latest developments in the field of

high-performance computing, quantum computing and artificial intelligence.

Pupils and students can look forward to experimental workshops at the Quantum Effects Academy and dive deeper into the fascinating world of quantum physics. The Quantum Effects Award seeks groundbreaking innovations from the quantum world and recognizes outstanding achievements.

In 2024, Quantum Effects will take place parallel to the hy-fcell (hydrogen and fuel cell technology), Vision (image processing, see below) and IN.STAND (Maintenance and Services).

www.quantum-effects.de



Preview: VISION

8 – 10 October 2024, Stuttgart, Germany

Held every two years, Vision presents the complete range of machine vision technology. In addition to first-rate exhibitors, the trade fair is characterized by its high degree of internationality and a varied accompanying program. Around sixty percent of exhibitors at Vision come from abroad, thus making it one of the most international trade fairs in the portfolio of Messe Stuttgart.

What technologies will have a decisive effect on the future of the industry? Interesting insights into trend top-

ics such as artificial intelligence (AI), hyperspectral imaging, embedded vision and 3D will be provided during the fair.

Hyperspectral imaging in conjunction with AI opens up many different application areas in medical technology, the food industry and, for example, the recycling industry. Embedded vision technologies offer intelligent application solutions by enabling very compact and highly efficient machine vision systems. 3D sensors are being used for

applications in the areas of electronics and e-mobility, for example the inspection of surfaces.

The special highlights in the area of trend topics at the event will be the Industrial Vision Days, the Scientific Vision Days and the presentation of the Vision Award. During the world's largest talk forum for machine vision, visitors will be able to experience technologies and practical applications which will shape the future of machine vision.

www.vision-messe.de



Preview: 14th Jena Laser Conference

6 – 7 November 2024, Jena, Germany

The organizers OptoNet eV, the Ernst Abbe University of Applied Sciences Jena (EAH), the Guenter Koehler Institute for Joining Technology and Materials Testing (IFW), and the Institute of Applied Physics (IAP) of the Friedrich Schiller University Jena will hold the upcoming Laser Conference. The alternating event will be held jointly with the Laser Center in Mittweida and will take place this year in Jena, in the EAH's Teaching and Congress Center. For the 14th time, information on the latest developments and current research

results on laser sources and laser material processing will be offered in a two-day program.

Participants can expect a varied program with a total of 6 keynote speeches, 28 scientific presentations, over 30 industry exhibitors and an extensive poster exhibition. This conference main topics are:

- Ultrafast lasers
- Ultrashort pulse laser processing
- Laser welding
- Laser processing of advanced materials

- Additive manufacturing
 - Metrology and characterization in laser processing
 - Optics and beam shaping
 - Advanced laser coatings and optics.
- This year, the organizers welcome Lithuania as a partner region, represented by the LITEK cluster, to enrich international collaboration and the exchange of innovative ideas at the fourteenth edition of the Jena Laser Conference in the "City of Light".

<https://lasertagung-jena.de>



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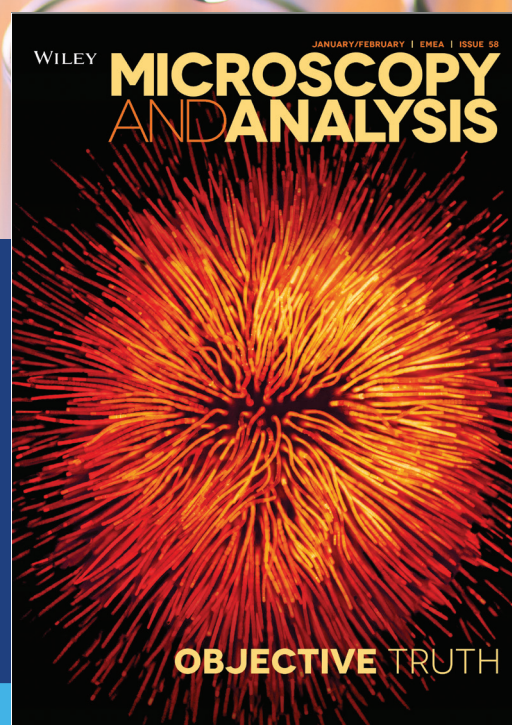
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