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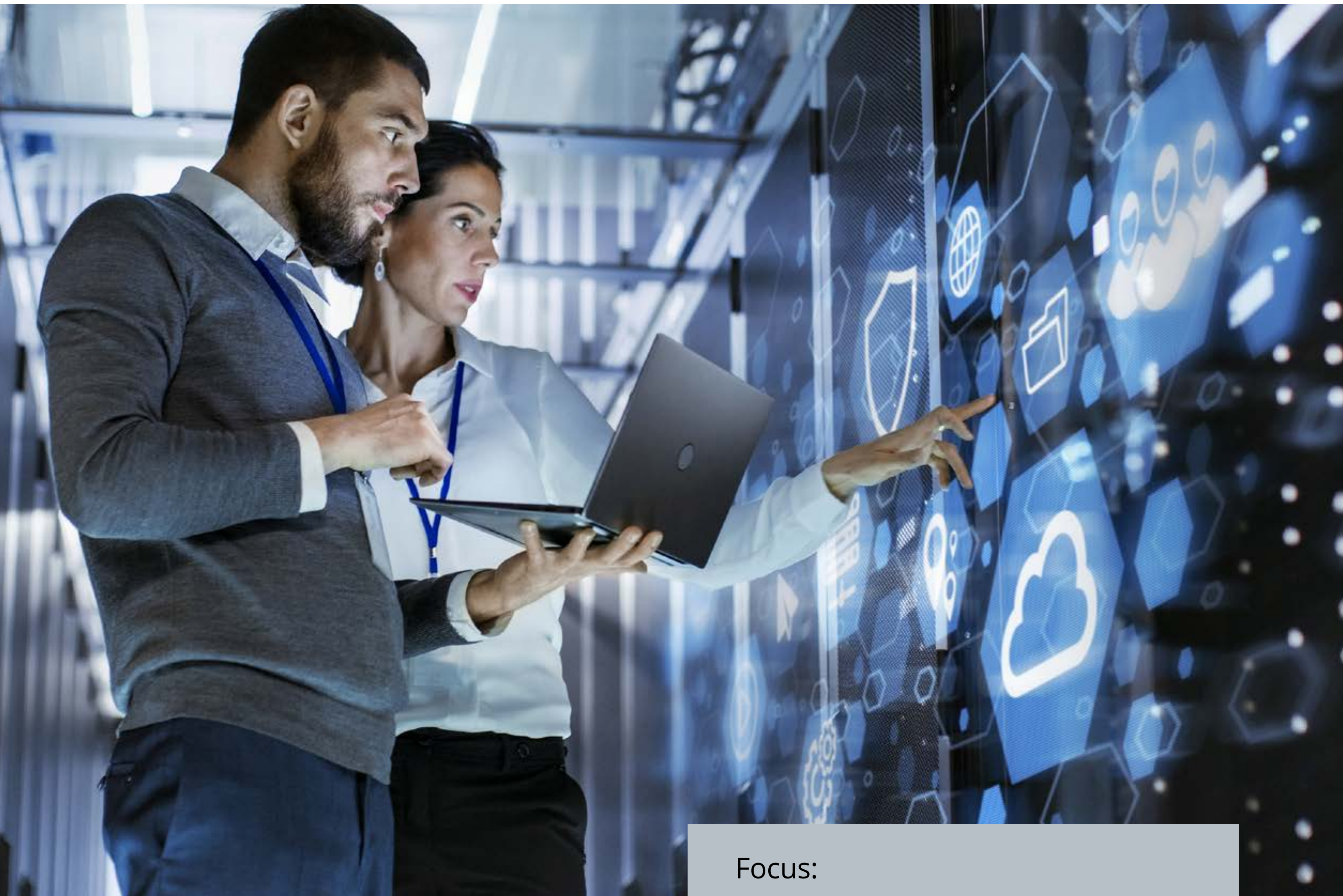
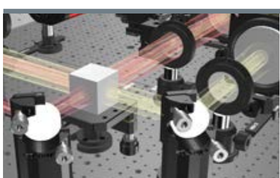
PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY

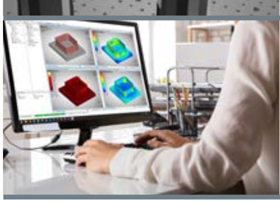


Focus:

Digital Tools, Design Software, Simulations



Optics Design
Cloud-based simulation tools for streamlined optical design



Additive Manufacturing
IMProVing directed energy deposition: avoiding distortions with simulations

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Develop and apply innovative methods and tools

What we can learn from nature in technology development

State-of-the-art optical technologies are characterized by the highest levels of precision possible today. At the same time, the step towards optical applications of tomorrow requires the synthesis of know-how of a wide variety of technology fields, such as materials science, optical surface generation, metrology and chemistry as well as mechanical engineering and software development. Consequently, it is essential to develop and apply innovative research methods that are capable of enabling such syntheses.

If we analyze how successful evolutionary development strategies take place in nature, we find new superior species that established themselves by being better adapted to new situations. One major aspect of this is often superior detection technologies in sight, hearing, sensing, and tasting, as well as superior communication capabilities, such as the human language, which enabled humanity to act fast, to adapt to new situations and to develop technological solutions to survive dangerous situations in nature.

With this in mind and the tremendously fast development of optical technology in both accuracy and diversity, we can identify interdisciplinary communication between different technology fields that are all necessary to develop next generation optical technologies – optical design, generation of metasurfaces, optical fabrication, interferometric sensing, laser technology and light-material interactions – as the major milestone to success.

Along that trail, the digitalization of processes needed in optical technology developments plays an essential role as it forms the foundation for better communication between the different fields of optical technology development. Therefore we need to put more effort into supporting interdisciplinary communication within optical technology fields by expanding conferences and exhibitions that focus on bridging different fields of technology, to further develop communication and to cultivate interdisciplinary ‘technology languages’.

Consequently, we should attend and support events like OSA’s Optical Design and Fabrication Congress and EOS’ Optical Systems Design, Tolerancing, and Fabrication Conference, which will take place this September in Rome. See you there!

Yours truly

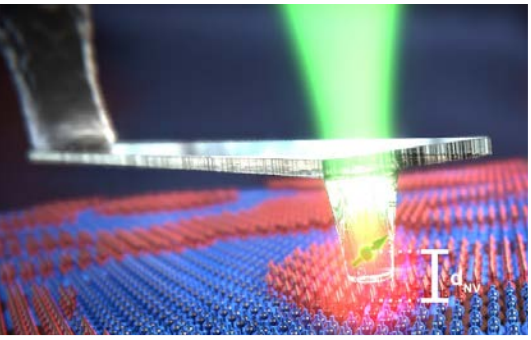
Oliver Faehnle

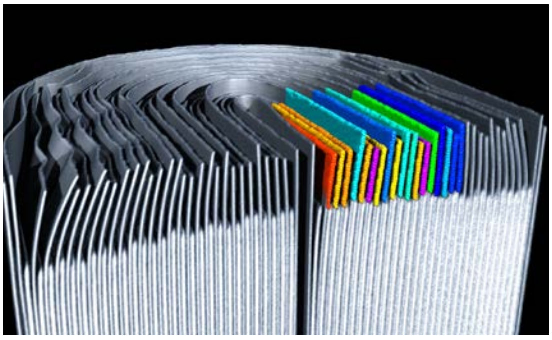
Dr Oliver Faehnle

Head, Optical Fabrication Technology Group
OST – University of Applied Sciences, Buchs, Switzerland

Co-editor of this issue

PhotonicsViews
OPTICS • PHOTONICS • LASER TECHNOLOGY





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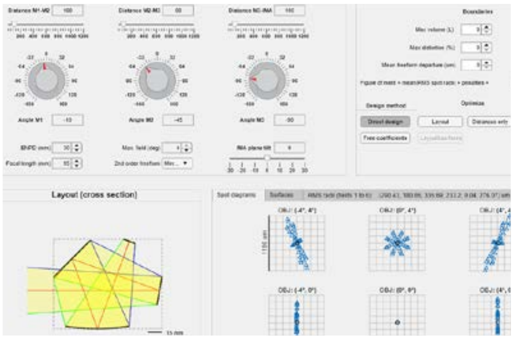


Cover:
Smart factories and optimized design and production environments rely on digital tools and cloud-based services
Source: Shutterstock / Gorodenkoff

VDMA: robotics and automation back on growth track

The robotics and automation sector in Germany will generate sales of 13.4 billion euros in 2021, an increase of 11 %, according to the forecast of the VDMA Robotics + Automation Association. Green technology strategies are important drivers of the economic recovery. In contrast, the year 2020 was still clearly negative, particularly under the impact of the Corona pandemic, although the decline in sales of minus 18 percent was more moderate than originally expected.

"The forecast for the current year shows a strong recovery and signifies a positive turning point for the industry," says Wilfried Eberhardt, chairman of VDMA Robotics + Automation. "In particular, order books are currently filling up fast. Even better sales figures will be achievable if the current supply bottlenecks for key components can be quickly overcome. The outlook into 2022 is excellent, as many complex projects now starting up will only be invoiced with a time lag. With the current momentum, the chances are good that we will already achieve – or even exceed – the record result from 2018 next year," explains Eberhardt.

Comparison of the three sub-sectors

The three sub-sectors developed differently in 2020: robotics revenue decreased by 23 % to € 3.1 B. Integrated assembly solutions recorded a decline in sales of 20 % to € 6.4 B. The machine vision sector lost a comparatively small 4 %: here, industry sales reached € 2.6 B. Overall, the revenue of the complete robotics and automation sector declined by 18 %.

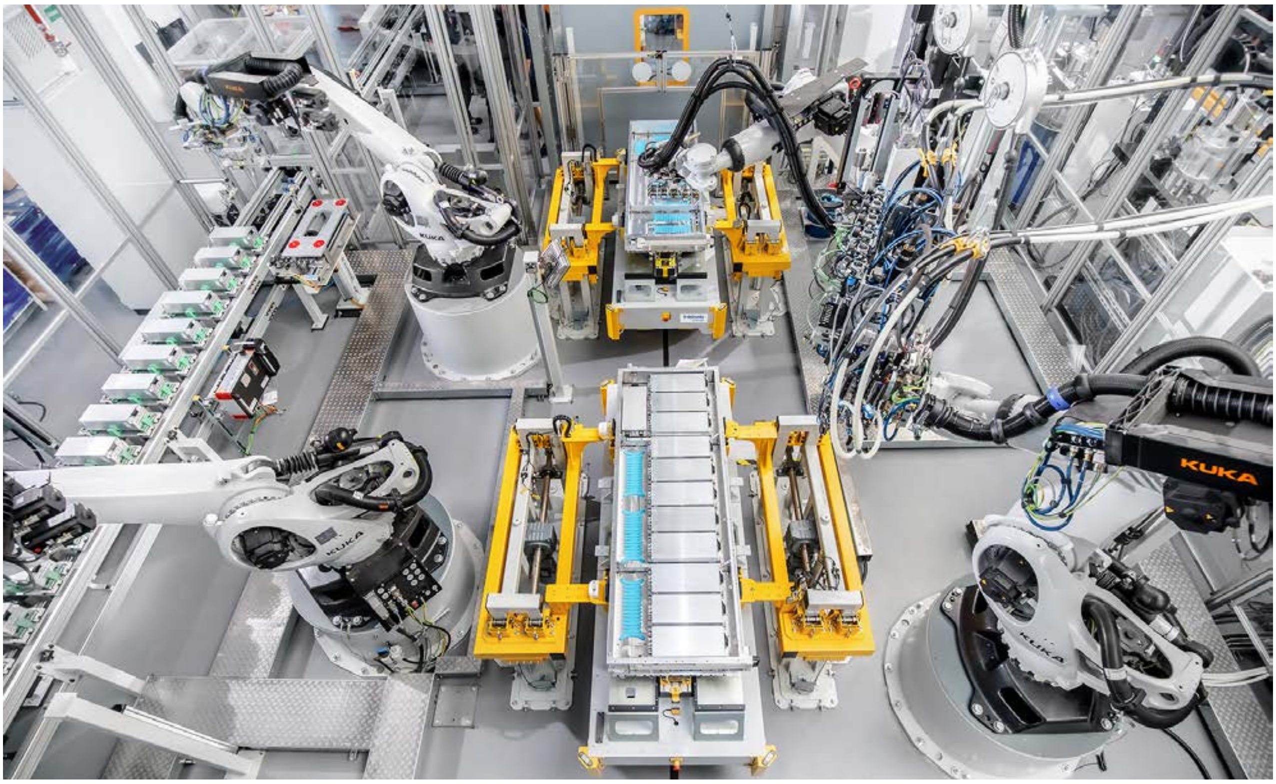
Impetus for the future

The robotics and automation business is characterized by strong pent-up demand: investments were postponed in the course of the pandemic and are now filling the order books. The transformation on the way to climate neutrality and a sustainable use of resources is also generating new business: robotics and automation are increasingly proving to be key technologies. Here are three examples:

In agriculture, low-cost field robots are helping to locate weeds using artificial intelligence and eliminate them selectively with lasers. Organic farmers halve their weeding costs with such an automation solution from the Cologne-based company Igus and UK startup Small Robot Company. At the same time it replaces the use of chemical agents.

The industry is relying on automation technology to be able to produce cells for hydrogen-powered cars in a cost and energy-saving manner in future. The German company Innocise, founded in 2019, together with Schunk, offers novel robotic grippers whose principle is inspired by nature. They use adhesive properties and operate without any external energy when gripping components. This significantly reduces energy consumption in production.

Powerful batteries are a core technology for decarbonisation – in the transport sector and in industrial production, in stationary storage technology and for the stabilization of electricity grids. Intelligent automation reduces production costs, which helps battery technology achieve a breakthrough in e-mobility and other areas. At the same time, highly efficient production technology reduces CO_2 emissions.



e-mobility: battery pack assembly line at Webasto (Source: Kuka)

Photovoltaics coming back to Europe

An impressive example of robotics and automation in the energy sector is currently the construction of one of the largest solar power plants in the world. The Constance-based company RCT Solutions is providing cutting edge production know-how and technology for this project. The automation experts are helping the client and operator in Turkey, one of the country's largest construction groups, to decouple itself from international supply chains for solar panels. In the first step, a specially built Industry 4.0 factory in Ankara is producing three and a half million solar modules. In a photovoltaic power plant in Konya, 260 kilometers away, these panels from the company's own production are installed directly after their production.

The aim is to generate one gigawatt of electricity from solar power in the final expansion phase – in the sixth largest solar power plant in the world. The investment volume is around 1.1 billion euros.

"In many European countries, people are currently thinking about rebuilding a complete photovoltaic value chain that includes all production steps," says Dr. Peter Fath, CEO of RCT Solutions and continues: "In Turkey, they have now shown that it works. It has already created 1,400 new jobs at the Ankara factory."

"The solar power plant in Konya shows where the journey is heading," adds Patrick Schwarzkopf, managing director of the VDMA Robotics + Automation Association. "We now must find ways of achieving the ambitious climate targets in reality. To do so, we need to scale renewable energies and environmental technologies to unprecedented dimensions. Robotics and automation enables us to achieve this with the highest quality and at competitive costs."

automatica sprint, 22 – 24 June 2021

This year, automatica sprint, a new trade fair format in the automatica portfolio, offered the robotics and automation industry a digital platform for exchange, knowledge and business. "The great response from the industry to our online format proves that we absolutely meet the special requirements of the current times," says Falk Senger, managing director of Messe München. Over eighty leading companies were participating in the digital trade fair format.

Great added value was also offered by Munich_i, a newly created platform for artificial intelligence (AI) and robotics. The central element was its High-tech Summit on 22 June. Under the motto "intelligence empowering tomorrow", experts from science and industry exchanged ideas on the interaction of human and artificial intelligence in the fields of work, health and mobility.

www.vdma.org/robotics-automation

IFR World Robotics Outlook: China leads post-pandemic recovery

The preliminary World Robotics data for China released by the International Federation of Robotics (IFR) shows a sales increase of industrial robots by 19 % in 2020.

"The outlook for the robotics industry is optimistic," says Milton Guerry, President of the International Federation of Robotics. "In China, where the coronavirus lockdown came into force first, the robotics industry already started to recover in 2020. In total 167,000 industrial robots were shipped."

Annual installlations of industrial robots worldwide (in thousands, preliminary; source: IFR)

Market growth in China also has a strong positive impact on foreign suppliers – up 24 % or 123,000 industrial robots were shipped from abroad. Japanese suppliers have a dominant market share. Domestic suppliers delivered 44,000 units to their home market which is an increase of 8 % compared to 2019.

Worldwide, North America and Europe

Global robot installations in 2020 were down 2 %, particularly under the impact of the Corona pandemic. Still, the decline in sales was more moderate than expected.

OECD projects global GDP growth to be 5.5 % in 2021 and 4 % in 2022. Nevertheless, the situation is mixed in different countries.

The order intake of the robotics industry 2021 gives reason to expect strong growth in North America and Europe. Order books in the US for example are filling up fast. In Germany, the forecast for the current year shows a strong recovery and signifies a positive turning point for the industry. Even better sales figures will be achievable if the current supply bottlenecks for key components can be quickly overcome.

Reduction of carbon footprint

The global path to climate neutrality is generating new business. In order to achieve the ambitious climate targets, economies have started to scale renewable energies and environmental technologies to unprecedented dimensions. Robotics and automation enable companies of all sizes to produce the components needed, e.g. fuel cells for hydrogen-powered cars or batteries in the transport sector and solar panels in the energy sector. The new generation of easy-to-use robotics helps to optimize performance in the production process and to move manufacturing closer to regional markets at competitive cost.

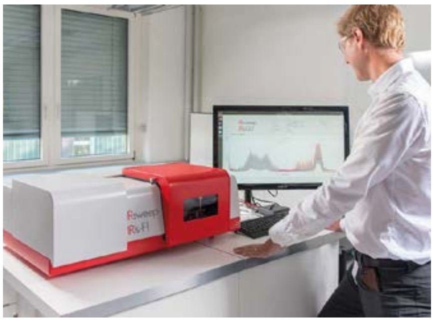
"Robotics have proven flexibility to quickly adapt production and respond to changes in demand as well as smaller batch sizes," says Milton Guerry. "The benefits of increased productivity safeguards jobs by keeping companies competitive."

Please also see the IFR video "Facts about Industrial Robots": https://www.youtube.com/watch?v=w_kApx8C-O4&t=1s

https://ifr.org

Sensirion fully acquires IRsweep

Sensirion Holding AG, a leading provider of environmental and flow sensor solutions, has completed the acquisition of IRsweep AG, based in Staefa, Switzerland, an innovative provider of optical sensing solutions. Sensirion has been a minority investor of IRsweep with 33 % of the shares since 2017. With this acquisition, Sensirion expands its optical sensing technology portfolio from components and modules to stand-alone infrared spectrometers for industrial and research applications.



IRsweep develops applications in mid-IR absorption spectroscopy. (Source: IRsweep)

Many spectroscopic applications in industry and research simultaneously require high spectral resolution and speed. IRsweep's infrared spectrometers based on its QCL frequency comb technology enable the very accurate study of fast processes such as protein dynamics or industrial reaction monitoring, without the need for moving parts.

IRsweep was founded in 2014, has eleven employees, and offers compact spectrometers based on its QCL frequency comb technology. Core applications of IRsweep's technology include the study of fast reaction kinetics in research and development applications. This acquisition allows Sensirion to strengthen its optical sensing technology portfolio enabling long-term development of cost-efficient sensing solutions based on optical measurement principles, such as trace gas analysis in environmental monitoring or the detection of methane leaks.

Andreas Hugi, Markus Mangold and Markus Geiser, IRsweep's founding team, comment: "We are excited to fully become a part of the Sensirion group, which will support us in expanding our reach and addressing new applications." The three founders will continue to act as IRsweep's proven management team.

"Sensirion very cordially welcomes all IRsweep employees and looks forward to joint developments of optical sensing solutions for air or water quality measurements," says Sensirion CEO Marc von Waldkirch. (Source: Sensirion)

www.sensirion.com
https://irsweep.com

Nanoscribe to become a Cellink company

Nanoscribe, a pioneer in high-precision additive manufacturing, strengthens its strategic position by entering the Cellink group. Cellink was founded in 2016 for commercializing the world's first universal bioink. The publicly listed company has consistently expanded its portfolio into a bioconvergence company offering solutions for bioprinting, multiomics, cell line development and diagnostics. Nanoscribe will continue developing high-precision additive manufacturing solutions as part of Cellink's bioprinting business area.

The life science industry is currently going through a very exciting transformation where many processes and technologies are being miniaturized to increase throughput and reduce cost, where the price of reagents is a major bottle neck for sequencing. One example is the sample preparation steps for single cell genomics applications.

With Nanoscribe's microfabrication technologies, Cellink stays competitive in this transformation and aims to miniaturize devices for a wide range of applications, resulting in internal capabilities to further expand its consumables offering across all business segments.

In its own estimate, the Cellink group will then be the world's first life science company with internal two-photon polymerization (2PP) additive manufacturing capabilities. Nanoscribe's 2PP technology enables bioprinting of vascular microenvironments at subcellular scale, suitable for cell studies and lab-on-a-chip applications, which is expected to contribute to the group's product development, yielding additional recurring revenue through the fabrication of implants, microneedles, microporous membranes, and consumables for omics applications.

There are several strong synergies by combining Cellink's cutting-edge macro structural bioprinting technology with Nanoscribe's microstructural bioprinting technology for more realistic tissue architecture, including vascularization, cell supports. The 2PP technology will enable a cross-functional adoption within all three business areas and enhance consumables product development and offerings of the Cellink group.

"With Nanoscribe's state-of-the-art 2PP technology, we will complement our product portfolio and offer a wider range of products to our amazing customers," emphasizes Erik Gatenholm, CEO of Cellink.

www.cellink.com
www.nanoscribe.com

Jenoptik expands optics manufacturing capacities

As a result of the increasing demand for optics and sensors for the semiconductor industry, Jenoptik intends to expand its manufacturing capacities and construct a state-of-the-art production building and a new office complex at the Dresden site. To this end, the company purchased a 24,000 square meter plot of land at Airportpark Dresden in May 2021.

Source: Jenoptik

Planning for a new Jenoptik clean room building and the modern office complex is now starting and should be ready for approval this year. As things stand today, construction is scheduled to begin in the 2nd half of 2022, with production at the new factory starting in early 2025. The company intends to announce further details once planning has been completed.

Within Germany, Dresden is an important location for the semiconductor industry, where many global companies and research institutions in the sector are present. But semiconductor manufacturers worldwide are also investing in expanding production capacity as demand increases in almost all areas of life due to digitalization. Jenoptik has been present in Dresden since 2007 and develops and produces optical components with lithographic processes as well as precision sensor modules there.

www.jenoptik.de

Evosys expands locations in US, China

Due to rapid growth, the Evosys branch in China has moved to other premises. Barely three years after its foundation, a move became necessary due to a lack of space. The new location offers almost twice as much floor space as before and a better working environment.

The branch in China was opened together with the Chinese partner DCT Co Ltd. in 2018. With its own technical center, which is equipped with a laser welding machine and the necessary measuring equipment to check weld seams, customers can have test welds performed on components within a very short time. The scope of services is complemented by experienced service technicians who take care of the systems at customers' premises, from commissioning to regular maintenance.

The Evosys group is also represented in North America and has moved into new premises near Detroit, Michigan, in Auburn Hills. The location has a floor space of over 2,400 sq. ft. and also has its own technical center and experts on site to provide support in all project phases. "At our well-equipped location, we can better accommodate the importance of the North American economy and provide sufficient space for new challenges," explains Frank Brunnecker, managing director of Evosys Laser GmbH.

Customer proximity is paramount for Evosys, because the company strives to achieve long-term and sustainable customer loyalty. The Evosys team always aims to be in close contact with the customer to be able to quickly take up and implement new requirements and developments.

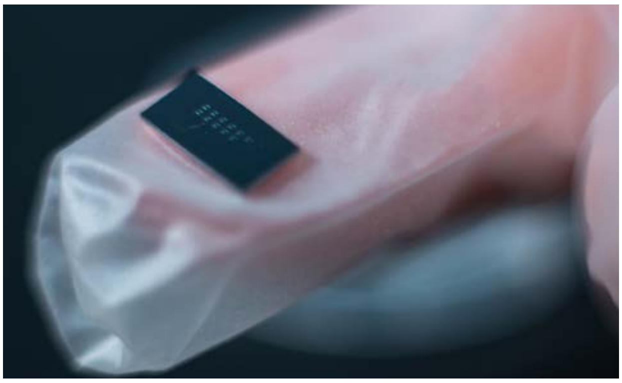
www.evosys-laser.com
www.evosys-laser.us

The team led by Frank Sun (2nd fr. r.) from the Evosys branch in Suzhou. (Source: Evosys)

Qurin Diagnostics and LioniX invest in Surfix

New investment in light-powered biosensors accelerates the availability of high quality, low cost tests for early detection of cancer, Covid-19, and other diseases.

Surfix announced an investment of 8.5 million euros by a Dutch consortium consisting of Qurin Diagnostics and LioniX International, industry accelerator PhotonDelta and the East Netherlands Development Agency Oost NL for further development of Surfix' plug-and-play diagnostics platform. Surfix will use the investment to accelerate the development of its fast, reliable and attractive plug-and-play diagnostics platform for all sorts of point-of-care tests .The initial target applications are early cancer diagnosis, Covid-19 detection and tracing of pathogens in water for aquaculture.


Biophotonic chip (Source: Surfix)

The global Covid-19 pandemic underlines the need for fast and reliable point-of-care diagnostics anytime and anywhere. The ultimate goal is to make a test that is available for the masses and at the cost of only a few euros.The Surfix biosensor consists of two significant elements: the most crucial part is the chip in which the actual sensing occurs. The other part is the microfluidics part, in which the biological assay takes place in a small sample volume.

In the sensing part, light passes through the chip (comparable to a minuscule glass-fiber spiral) instead of electricity. Biomolecules attached to the surface of the chip can catch other biomolecules out of a sample based on biorecognition.

www.surfixdx.com
https://qurin.com

Vision Components turns 25

Embedded vision specialist Vision Components celebrates its 25th anniversary in 2021. The company wants to celebrate this occasion with a webinar series and a hackathon under the motto: "This has to work better" – a mindset that Vision Components considers typical for itself.

In 1995, Managing Director Michael Engel developed and presented the world's first intelligent camera suitable for industrial use. By founding the company the following year and entering series production, he left a lasting mark on the market for industrial machine vision. The freely programmable cameras provided OEMs with great flexibility in developing customized solutions for all conceivable vision applications.

Many tasks could now be solved in a space-saving manner without image processing computers and control cabinets. The first generation of smart cameras was soon followed by Vision Components' next innovations, including the first intelligent vision sensors and embedded 3D laser profile sensors.

Most recently, the manufacturer unveiled the VC Picosmart miniature embedded vision system. It is fully functional, with all components for image acquisition and processing, including FPGA and FPU, and is as small as a conventional image sensor module.

In addition, Vision Components is now also involved in the development and manufacture of MIPI camera modules for flexible embedded vision designs based on single-board computers.


Michael Engel (Source: Vision Components)

www.vision-components.com

Zurich Instruments has become a Rohde & Schwarz company

The Rohde & Schwarz technology group, a player in future areas such as 6G and autonomous driving, will now also be active in the field of quantum computing. The July 1, 2021 acquisition of Zurich Instruments AG, a technological leader in test and measurement, will help Rohde & Schwarz further expand its test and measurement division. The Swiss company will be run as a full subsidiary.

Source: Zurich Instruments

Adrian Messmer, Flavio Heer, Sadik Hafizovic, Jan Benhelm, Stephan Koch (l. t. r.)

Zurich Instruments was founded in 2008 and has grown into a company with over one hundred employees with offices in China, USA, France, South Korea, Italy and Japan. Since 2015, it has been committed to providing the best control systems for researchers building quantum computers. The field of quantum computing requires the best and latest technology.

"In Rohde & Schwarz, we found a company that can provide us with access to such technology. Their size, stability and technological expertise offer optimal conditions for us to remain a leader in the rapidly growing quantum computing market and continue to grow as an independent subsidiary," said Dr. Sadik Hafizovic, co-founder and CEO of Zurich Instruments.

"We are looking forward to developing technological solutions for the future together with Zurich Instruments. We are also strengthening our position in the scientific realm. Rohde & Schwarz and Zurich Instruments already share a passion for advancing science and innovation," said Peter Riedel, president and COO of Rohde & Schwarz.

Zurich Instruments' customers can expect further innovations in lock-in amplifiers, impedance test and measurement instruments and quantum computing control systems. Continuing the relationships with existing customers and partners is essential to both companies. All functions will remain in place, from development and production to marketing and sales. (Source: Zurich Instruments)

www.zhinst.com
www.rohde-schwarz.com/de

HD Vision Systems becomes a partner of Bosch Rexroth ctrlX automation platform

Users get quick and easy access to apps for industrial image processing: HD Vision Systems is now making functions and interfaces to standard area scan cameras available as a vision suite in the ecosystem of the ctrlX automation platform from Bosch Rexroth. In addition, the two companies are developing customer-based machine vision applications and a use case for object recognition and oriented positioning using a Cartesian robot.

As a specialist in industrial image processing, HD Vision Systems supports production companies with hardware and software products based on light field technology and deep learning – whether for quality inspection, handling of workpieces or 3D scanning. From now on, the company will offer the Vision Suite from HD Vision Systems as an image processing app for the ctrlX CORE control platform in the ctrlX App Store together with Bosch Rexroth.

At the same time, Bosch Rexroth and HD Vision Systems are also developing joint customer-based machine vision solutions. A first use case deals with object recognition and oriented placement using a Cartesian robot. Components are automatically recorded using a 2D camera system that is connected to the ctrlX CORE controller via Ethernet. The Vision Suite processes the images and identifies the components, determines their position and makes the data available to the robot for accurate gripping.

They are then stored in a predefined grid. This enables further processing in downstream processes.

www.hdvisionsystems.com

On the way to mass production

The Dresden high tech company Senorics has closed an eight million euros pre-series A financing round. The money allows for the necessary investment to scale the innovative material analysis sensor technology for the industrial market. The circle of investors was joined by Fidura Private Equity as lead investor and Zeiss Ventures. The previous cooperation with Ventura Investment, the Technologie Gründerfonds Sachsen (TGFS) and the TU Dresden AG will also continue. They have participated in the current financial round with a significant investment and have been supporting Senorics since 2018, when they took part in the seed funding.

Source: Senorics

Near-infrared inspection of a wafer

The German company specializes in novel near-infrared spectroscopy sensors. They are smaller than a one cent coin and can be integrated into household appliances and smartphones. The sensor enables the contactless analysis of material compositions, which until now was only possible in laboratories using bulky spectrometers.

In infrared spectroscopy, a solid or liquid material is irradiated by light. Material compositions can be identified and quantified based on the wavelength distribution of the reflected light. In an industrial context, for example, the technology enables process monitoring and quality control because of its ability to detect contamination.

www.senorics.com

Germany grants Optics University Center and Campus in Hanover

On April 23rd, the German Science Council (Wissenschaftsrat) recommended the funding of the Opticum research building – Optics University Center and Campus. Hannover University shares first place on the funding list with the universities in Marburg and Münster. It will be financed – subject to the Joint Science Conference's final decision – with 54.2 million euros. The federal government and the state of Lower Saxony will each contribute half of the funding.

"Our Opticum will be the research building for all scientists from the disciplines of physics, mechanical engineering, electrical engineering, mathematics, computer science and chemistry working together on the digitalization of optics research and optics production," says Prof Uwe Morgner. The physicist is the spokesman of the board of the PhoenixD Cluster of Excellence.

The 120 optics researchers are investigating how they can realize complex optical systems in a short development time and for a fraction of today's price. To achieve this aim, the Hanover scientists join their forces with project partners from the Technical University Braunschweig and the Laser Zentrum Hannover.

The planned Opticum has four floors and a usable area of just over 4,000 square meters.

www.uni-hannover.de


Source: U Hannover

Design for the planned OPTICUM research building

New technology center to accelerate digital innovation

On 2 June 2021, the integrated photonics industry accelerator PhotonDelta, research institute TNO, Eindhoven University of Technology and University of Twente will sign a co-operation agreement for the new Photonic Integration Technology Center (PITC) in the Netherlands. This center will speed up the commercialization of Integrated Photonics for applications such as autonomous mobility, healthcare, data, and communications.

Integrated Photonics is represents a revolutionary technology that enables the development of chips that can sense, capture and process huge amounts of data using light instead of electricity. By using light, we can create new types of devices and systems, complementary to those that use electronics. Photonic integrated circuits pave the way for devices and systems that are cheaper, faster, lighter, more robust and reliable while using less energy. This opens new perspectives for developing purposeful digital solutions.

The new PITC is an independent R&D and innovation center that brings photonic technologies to industrial maturity, builds partnerships, strengthens the photonics ecosystem, and links it to a global customer base.

https://pitc.nl

EMBL Imaging Center getting ready for user access

The new EMBL Imaging Center for the life sciences is preparing for operations after an on-time and on-budget build and handover, and is expected to welcome its first users in a pilot phase later this summer, followed by the first open call for users. EMBL director general Edith Heard says: "The opening at EMBL's main site in Heidelberg, Germany, is an important moment for the European science community. Research in the life sciences is being revolutionized by advances in imaging, genomics, and gene editing, and provision of access to advanced technologies is key to enabling scientific progress."


Imaging Center (Source: EMBL, K. Lubowiecka)

"I hope that the EMBL Imaging Center will play a significant role in shaping a new era in the life sciences, and that scientists from many different areas will benefit from it. EMBL has pioneered many of the imaging technologies that scientists use today, and the Imaging Center will provide a unique opportunity to benefit from such technology development," the professor continued.

www.embl.org

Zeiss Innovation Hub in Dresden opens its doors

In late May, the team at the Zeiss Innovation Hub in Dresden got down to work. An official opening ceremony for the Hub will take place once it is permissible. For the first Hub program – research into organoid models – Dr Kai Wicker and his team have moved into the EKFZ for Digital Health on the campus of the Carl Gustav Carus University Hospital – a stone's throw away from top experts in the field.

This proximity to academic partners such as the TU Dresden, the University Hospital and the Leibniz and Max Planck Institutes, as well as to startups and innovative companies in the region, allows Zeiss to benefit from an exceptional research and innovation ecosystem. The goal is to maximize local engagement and scientific exchange while benefitting from synergies to promote talented young researchers.

Zeiss plans to quickly grow the Innovation Hub in terms of both its focus topics and its workforce. To this end, new staff will initially be hired to work primarily on the organoid program, and on the variety of topics that go beyond the initial focus on biomedicine. Alongside the life sciences and medical technology, the Hub team sees potential for further links, with digital technologies, microelectronics and


Dr Kai Wicker (Source: Zeiss)

informatics, as well as with artificial intelligence, nanotechnology and materials research.

www.zeiss.de
www.tu-dresden.de

M-Fibre side light fiber system wins innovation award

M-Fibre, the flexible side light fiber system from Mentor Präzisions-Bauteile, has won the German Innovation Award 2021 from the German Design Council. the Excellence in Business to Business competition class.

The German Innovation Award recognizes products as well as processes and services with particularly innovative

Managing partner Dennis Weyer, Wido Weyer and CTO Wolfgang Mursch (left to right; source: Mentor)

With this award, the international center of expertise for communication and knowledge transfer in the fields of design, branding and innovation recognizes products and projects with particular innovative strength. The system impressed the judges in the Lighting Solutions category and was named "Winner" in added value compared with previous solutions in various categories. An interdisciplinary and independent jury consisting of experts from industry, science, institutions, and finance, singled out Mentor's M-Fibre side light fiber system as a product innovation that stands out with its originality, implementation and effectiveness, as well as the progress achieved through its use.

Due to the pandemic, the prize-winning companies and products will not be awarded in the German Museum of Technology in Berlin as usual, but during an extensive online program.

"We are especially pleased about M-Fibre winning the German Innovation Award," says Wido Weyer, owner and managing director of Mentor. "The Innovation Award is a recognition of one of our most important elements: our focus on innovative technologies. With our products and solutions, we are contributing towards developing multifunctional, individual and promising products and applications," he states. This is also the case with M-Fibre, our thin and flexible side light fiber system, which is used as functional or decorative linear lighting in both the consumer and industrial goods sector."

In keeping with the theme of "added value through light", the innovative lighting solution in product and industrial design opens up numerous ways of adding functional or emotional values to a wide variety of products. Hotel or rental furniture can be illuminated in individual corporate design colours, for example. Integrated in traffic cones, access controls on public transport or lifebelts, M-Fibre provides orientation and safety and can even be used as an additional communication component in electrical appliances.

Other winners in 2021 include Continental Automotive, Häfele, Laservision, LED Linear, Ledvance, Schott, and Trilux. (Sources: Mentor, Rat für Formgebung)

www.mentor.de.com
www.german-innovationaward.de

Fresnel prize and early career women in photonics award for Milano physicists

Dr Margherita Maiuri, researcher of the Politecnico di Milano's department of physics, received the Fresnel Prize by the European Physical Society for significant contributions to quantum electronics and optics made by scientists under 35 years of age.

Maiuri received the award "for outstanding achievements in ultrafast optical spectroscopy, unveiling primary light-induced processes in biomolecules and nanostructures with sub-10-fs pulses".

Maiuri obtained her PhD research degree at Politecnico di Milano in 2014, specializing in ultrafast optics and spectroscopy. After her doctorate she worked as a research fellow at Princeton University. In 2015 she won a Marie Skłodowska-Curie global fellowship.

She is currently assistant professor of the department of physics, where she deals with multidimensional electronic spectroscopy for the study of light-energy conversion mechanisms in complex systems. Her current research interests include understanding the dynamics of femtoseconds of light-induced mechanisms in biological and biomimetic systems and nanostructured complexes. She works in the team of Prof Giulio Cerullo.

Also at the Polimi physics department, Dr Rocío Borrego Varillas was awarded the early career women in photonics award by the European Optical Society, to honor a young female scientist who has made outstanding contributions to photonics. Borrego Varillas obtained her PhD in physics from the University of Salamanca, with research

Source: PoliMi

Dr Rocío Borrego Varillas (l.), Dr Margherita Maiuri

stays at the Max Planck Institute of Quantum Optics and Universitat Jaume I. In 2013 she was awarded a Marie Skłodowska-Curie fellowship to conduct her postdoctoral research at Politecnico di Milano.

At present she is a researcher at the Istituto di Fotonica e Nanotecnologie (IFN) of the CNR, where she is responsible for the scientific activity in the joint IFN-Polimi lab for attosecond dynamics in molecules. Her research interests include few-cycle pulse generation in UV, ultrafast spectroscopy of biomolecules and sub-femtosecond electron dynamics. She works in the team of Prof Mauro Nisoli.

The official award ceremony took place on 22 June 2021, during the CLEO online conference.

www.polimi.it

OLED pioneer Karl Leo receives European Inventor Award 2021


Source: EPO

In a career spanning over 30 years, Leo (2nd from left) has channeled many of his research breakthroughs into commercial successes.

The European Patent Office (EPO) has honored German physicist Karl Leo with the European Inventor Award 2021 in the "lifetime achievement" category. Leo's method for boosting organic semiconductors with electron-producing substances ("doping") has transformed the electronics industry and delivered improved products for millions of people. His highly efficient organic light-emitting diode display technology, which provides greater image brightness, higher color resolution and better power efficiency, can now be found in almost all newer smartphones and other electronic devices that we use every day.

"Leo's work has had a profound impact across multiple sectors, advancing technology which is environmentally friendly, and improving products that are used by millions of people worldwide," said EPO president António Campinos. "Throughout his distinguished career he has also demonstrated an ability to identify commercial applications from cutting-edge fundamental research, putting technology to work to solve problems, and creating businesses and jobs in the process."

This year's European Inventor Award ceremony was held digitally, and for the first time was open to the public who tuned in from around the world. The award is presented annually by the EPO to distinguish outstanding inventors from Europe and beyond who have made an exceptional contribution to society, technological progress, and economic growth. The finalists and winners in five categories were selected by an independent international jury.

Leo's early fascination with household electronics – his passion for repairing things earned him the nickname 'the technician' among family members – later ignited his interest in semiconductors. This became the focus of his undergraduate thesis at Freiburg's Fraunhofer Institute for Solar Energy Systems ISE in 1985, where he began to think about how electronic devices could be improved.

His PhD and early post-graduate career concentrated on inorganic semiconductors – at the time considered impractical due to their poor electrical conductivity and short lifespan. Leo noticed that few people had considered doping for organic semiconductors.

Leo achieved his key breakthrough in 1998, when he and his team of researchers at TU Dresden, including then PhD students Martin Pfeiffer and Jan Blochwitz, successfully created an organic semiconductor LED requiring only one-fifth of the voltage previously needed. These organic semiconductors were also more sustainable than inorganic semiconductors due to their high efficiency, long lifespan, low-energy production process and potential to be recycled. Leo and his team continued to refine the process further, and in 2001, he co-founded the German start-up company Novaled AG – later acquired by Samsung – to commercialize these OLED technologies and materials.

Leo later began adapting semiconductors to function in organic solar cells, which led to him co-founding the spin-off behind the world's first industrial-grade organic solar film that can be mounted on buildings.

www.epo.org

Sir David Payne is recipient of the Berthold Leibinger Zukunftspreis

Professor Sir David Payne of the University of Southampton is the eighth recipient of the Berthold Leibinger Zukunftspreis. The jury of renowned international experts and industry leaders recognized Sir David's work on the "Erbium-doped fiber amplifier (EDFA) and pioneering research in fiber optics technology".

Since the 1970s, Sir David's work has spanned many diverse areas of photonics, from telecommunications and optical sensors to nano photonics and optical materials. Together with his colleagues at the University of Southampton's Optoelectronics Research Center, he has made many of the key technical achievements in almost every area of optical fiber technology and his work has had a direct impact on worldwide telecommunications, as well as nearly all fields of optical R&D. He is particularly noted for work on the erbium-doped fiber amplifier in telecommunications and high-power fiber lasers in material processing.

The Berthold Leibinger Stiftung presents professor Sir David Payne with the Berthold Leibinger Zukunftspreis, also recognizing his entrepreneurial spirit in initiating and sparking commercialization by founding a number of start-up companies, as well as his numerous collaborations with well-established technology companies.

The award ceremony of the Berthold Leibinger Innovationspreis and Zukunftspreis 2020 has had to be postponed for the second time. It will finally take place on Friday, September 24, 2021 in Ditzingen. Bringing together many people from different countries to celebrate outstanding innovations in laser technology would still be impossible to achieve beforehand. The Zukunftspreis prize winner and all eight finalists of the innovation prize will be honored, and the three prize winners will finally be announced.


Sir David Payne (Source: U. So'ton / BLS)

www.leibinger-stiftung.de

Rauscher GmbH with changed company structure

Following the unexpected death of company founder Ernst Rauscher in November 2020, the management and shareholder structure of the supplier of hardware and software components for industrial and scientific machine vision has now been reorganized. Raoul Kimmelmann, who had already been working alongside Ernst Rauscher as managing director since 2013, will lead the company together with Thomas Miller as additional managing director.

Source: Rauscher

Raoul Kimmelmann (left), Thomas Miller

Miller has had overall responsibility for technology, application and support at the company since 2006. He is also one of the four nephews of the company founder who make up the Rauscher community of heirs. As the fifth shareholder, Kimmelmann also has an equal share in the company with immediate effect.

"In the almost four decades under his [Ernst Rauscher's] leadership, the company has developed excellently and has become a firm, recognized force in machine vision. Continuing the positive development of Rauscher GmbH successfully in the future is our primary goal. As a management team with many years of proven experience, we stand for experience and continuity for our customers, suppliers, business partners and employees. Rauscher is and will continue to be a reliable partner for the development of powerful machine vision systems and the selection of the optimal components and technologies for this purpose," declared the managing director duo Kimmelmann and Miller.

www.rauscher.de

Laser Components introduces the new head of the Detector Group

Source: Laser Components

Raj Chakraborty (left), Dragan Grubisic

Earlier this year, Dr Raj Chakraborty took over the Laser Components detector group from Dragan Grubisic, who was retiring from day-to-day operations after 17 years at the helm but will continue to be available to the company for development projects.

Chakraborty has worked closely as operations manager with his predecessor since 2018. In this role, he managed the day-to-day operations of the production and engineering teams. He expanded the team's core competencies and increased the number of employees from 27 to 40. Chakraborty has more than 24 years of experience in the semiconductor industry. He worked for various Fortune 500 companies during this time. As an expert in lean manufacturing, he was instrumental in planning the new company building in Chandler, Arizona, which was completed in late 2020.

Grubisic's expertise in detector development played a decisive role in the expansion of the product portfolio and the continuous growth of the company. Under his leadership, the group grew from a small production facility with just a few employees to one of the company's most important locations.

www.lasercomponents.com

Robert Bauer retires – change at the top of the Sick management board

The sensor manufacturer Sick is changing the top of its management on October 1: Dr Robert Bauer will take his leave and Dr Mats Gökstorp will follow to take his place as CEO. At the same time, Dr Niels Syassen will be appointed to the executive board. He will assume responsibility for technology and digitalization.

Dr Mats Gökstorp

Dr Robert Bauer

Dr Niels Syassen

Source 3 images: Sick

So Sick AG will bid farewell to its long-serving CEO Dr Bauer on September 30, 2021, after twenty years of service. His move to the top of the supervisory board is planned for May 2022, where he will succeed the retiring chairman Klaus Bukenberger.

Gökstorp has been responsible for products and marketing since January 1, 2021. He will continue to hold this position after becoming chairman of the executive board. The computer scientist and engineer joined the company in 2003 with the acquisition of Sick IVP. As a member of the executive board, he was responsible for vision products and later for sales processes in the group from 2007 before being appointed to the board for sales and service in 2013. In recent years, he has been responsible for the global alignment of sales structures.

Dr Niels Syassen has been responsible for the gas and particle analysis solutions division since 2018. Before joining Sick in 2017, he held management positions in product development at Bosch and at Dräger Safety. He studied physics with a focus on lasers, optics and semiconductors at TU Munich and Imperial College in London. In 2008, he received his doctorate from the Max Planck Institute for Quantum Optics.

www.sick.de

Isra Vision: Founder and CEO Enis Ersü retires

After 36 years at the helm of Isra Vision, Enis Ersü retired in June 2021. A successor has already been found in Tomas Ludin for the vacant position on the executive board.

Enis Ersü, a research assistant at the time, founded Isra Vision as a spin-off from TU Darmstadt. The company was one of the first to strategically focus its business case on combining machine vision with robotics and automation. This is reflected in the name: Isra, which stands for intelligent systems, robotics, and automation.

After the first ten years, the decisive step was taken with a focus exclusively on machine vision. Isra Vision has been listed on the Frankfurt Stock Exchange since 2000. Today, the company has 25 locations in over 15 countries. More than 850 employees generated sales of approximately € 129 M (FY 2019/20). The year before, sales were just under € 154 M.


Enis Ersü (Source: Isra Vision)

"I have had the privilege of working with a great team for more than 36 years; I am grateful to all my employees, colleagues, customers and partners who have accompanied me at many interesting stages, and have supported changes, strategic measures and courageous decisions," says Ersü.

The company is currently headed by a three-member management team: Tomas Lundin recently joined the team. The board members Hans Jürgen Christ and Dr Johannes Giet continue their appointments.

In addition, Ersü is convinced that, with the takeover by the Atlas Copco Group, it has found a sustainable industrial partner with which Isra Vision can continue to pursue the growth path it has embarked upon.

www.isravision.com

Cornelia Denz takes office as PTB President in 2022

Joachim Ullrich, who has held the presidency since 2012, is retiring due to age. Cornelia Denz is no stranger to the PTB (Physikalisch-Technischen Bundesanstalt) – and vice versa. For many years, she has been involved in the PTB's board of trustees and is therefore very familiar with the tasks and objectives of the federal institute. "I am very pleased about this appointment," says Denz. "I will work to ensure that PTB, with its far-reaching metrology, will make a pioneering contribution to the systemic challenges of the upcoming technical and societal transformations."


Source: WWU Muenster, E.Huelsheger

Prof Dr Cornelia Denz

Her scientific career led her from the TU Darmstadt, where she qualified as a Professor with her thesis on structure formation in nonlinear optics, to the University of Münster. There she has headed up experimental physics with a focus on applied physics since 2003. She has also been director of the Institute of Applied Physics since 2004. Denz is internationally known for her work on complex light structuring, which she applies in nanophysics, biomedicine and information technologies together with her Nonlinear Photonics research group. From 2010 to 2016, Denz was vice-rector for international affairs and young scientists at Münster University.

Denz has received numerous awards, including the Lise Meitner Prize of the State of Hesse. She has been a member of the Academy of Sciences and Arts of the State of North Rhine-Westphalia since 2014.

In the long tradition of the PTB (the predecessor institution, the Physikalisch-Technische Reichsanstalt, PTR, was founded in 1887), Denz will be the first woman to hold the office of president after fourteen presidents before.

www.ptb.de

Jennifer Cable named president of Thorlabs

Thorlabs has announced that Jennifer Cable has been named president of Thorlabs, a vertically integrated manufacturer of photonics equipment. Since its establishment in 1989, Alex Cable, her father, has served as both president and chief executive officer, growing a fledgling startup, operating out of his garage, into a thriving multinational organization that employs over two thousand individuals with sales and manufacturing facilities in nine countries. Alex will continue to guide the privately held organization he founded through his role as CEO.

Since joining the company in 2015, Jennifer has held a variety of positions that have leveraged her previous experience leading a strategy team that developed and executed strategic plans for Horizon Blue Cross Blue Shield, a major company in the healthcare industry. Prior to that, she earned an undergraduate degree in philosophy from Vassar College and a master's degree in bioethics from Columbia University, and worked for Population Services International in Laos as a Princeton-in-Asia Fellow.

"I'm thrilled to have an opportunity to co-lead with my father the company he founded. Even as a child, I was aware of the fundamental values he instilled to guide the organization – curiosity, commitment to the sciences, and loyalty to our customers and employees," commented Jenn. "It's my goal to continue his vision as we look to build on our 30+ years of success and strong growth."


Source: Thorlabs

Jennifer Cable

"I remember fondly back to the early days of Thorlabs when I used to bring Jenn to work with me," noted Alex. "Over the last few years, I've enjoyed watching her immerse herself in all areas of the business, and since the start of the pandemic, she's been a de-facto member of our executive team, guiding us through this crisis. Her passion and dedication to Thorlabs are equal to my own."

www.thorlabs.com

Laser Components USA: new general manager appointed

Matt Robinson is the new general manager and COO of Laser Components USA, Inc. He previously served as sales director for five years.


Source: Laser Components

Matt Robinson (l.), Gary Hayes

The industrial engineer has been with Laser Components USA since 2006. In 2016, he became sales director. Overall, Robinson has been in the photonics industry for more than 30 years. Prior to Laser Components, he was a product manager and sales manager for Corning Inc. and Schott AG. Throughout his career, he has built a reputation as an expert in pulsed laser diodes, avalanche photodiodes and IR components, and LiDAR technology.

Laser Components was founded in 1982 as a one-man company and is now a group of companies with sales offices and manufacturing facilities on both sides of the Atlantic. Laser Components USA, Inc. has been responsible for sales, marketing and distribution in North America since 2000. Its broad portfolio includes IR components, photodiodes, pulsed laser diodes, laser modules and laser optics. All these products are manufactured to customer specifications within the group. The range is supplemented by components from selected suppliers around the world.

www.lasercomponents.com

Britta Schulz is interim board member of LPKF

The supervisory board of LPKF has chosen Britta Schulz as temporary board member to serve the interests of the company and its shareholders and provide CFO Christian Witt with the support he needs until a new CEO is appointed. Both Witt and Schulz have commercial/business professional backgrounds.


Source: LPKF

Britta Schulz (Source: LPKF)

"I appreciate the trust placed in me and look forward to an exciting time in a dual function as head of the business unit DevelopmentQuipment and member of the management board," says Schulz. The manager started her career at LPKF 25 years ago. Since that time, she has garnered a great deal of respect – in the "LPKF family" as well as among customers and suppliers. In 1996, she joined the company – already a high-tech firm at that time. She assumed responsibility for sales and marketing in the development segment in 2004 and has been heading up this business segment with great success since 2010.

For Schulz, there is no question as to how she can combine the two task areas as head of a business segment and member of the management board in a personal union: "Organizationally, we will ensure that despite my dual role during this time, all processes will continue running optimally," Schultz assures.

www.lpkf.de

Lynred names Jean-Yves Dussaud as CMO

Lynred, a global provider of high-quality infrared detectors for the aerospace, defense and commercial markets, created two years ago as a merger between Sofradir and Ulis, has appointed Jean-Yves Dussaud as chief marketing officer. His new role is one of several strategic moves the company has undertaken to bring more ambitious and innovative value-added propositions to its key markets.

Previously Mr Dussaud was chief quality and risk officer at Lynred. He has ten years' management experience within the firm, which includes seven as a member of the board. Prior to that, he held B2B and B2B2C product manager positions at international firms Rieter (CH) and ITW (US), accumulating seven years' international marketing experience.


Source: Lynred

Jean-Yves Dussaud

Jean-François Delepau, chairman and CEO of Lynred states: "Jean-Yves has the leadership to enable us to better tailor our offer to the future needs of clients, who are developing products in emerging applications. The whole company is geared towards more market diversification and to developing smaller footprint, value-added IR products in greater volumes."

www.lynred.com

CFO Kathrin Dahnke leaves Osram board

The supervisory board of Osram and CFO Kathrin Dahnke agreed to terminate her contract on June 30 by mutual agreement. With the planned delisting of Osram Licht AG, which is expected to be implemented by the end of June, major functions of the Osram CFO will become superfluous. Kathrin Dahnke's other responsibilities will be taken over by CEO Ingo Bank, who is also CFO at the parent company AMS.

Supervisory board chairman Dr Thomas Stockmeier thanked her for her important contribution. "Kathrin Dahnke did an outstanding job during the transition period of the past year. Thanks to her the integration of Osram and ams can proceed so efficiently," Stockmeier explained. "Kathrin Dahnke kept both the interests of the shareholders and the overall good of the company in mind during the complex processes."

Since taking office in April 2020, Dahnke contributed to the advanced realignment of the industrial group from a traditional lighting manufacturer to an innovative high-tech champion. She was in charge of the preparatory measures for the domination and profit and loss transfer agreement by ams, which was approved by the shareholders with a large majority at the beginning of November.

Actions during her term consisted of hundreds of operational and financial measures across all business units and generated an earnings effect of more than € 50 M and a free cash flow lift of € 132 M in the past fiscal year.

www.osram.com

Product of the Month

Compact 8 ps laser for precision micromachining

Manufacturer: Novanta/Laser Quantum.
Product: Reliable 8 ps laser "Dart" for high precision processing like micro-drilling and cutting in a range of materials from PCBs to probe cards, and glass to stainless steel.
Features: The laser displays beam roundness over a large depth of field, >93 % over ±3 Rayleigh lengths. Thus, high aspect ratio and symmetric features can be achieved with zero taper and a smooth surface finish.
The laser has been specifically engineered for OEM users and offers a straightforward integration pathway with one single supplier for both laser and scanning sub-systems. As standard, "Dart" features precision boresighting specifications that reduce the complexity of optical alignment during installation. With a ruggedized, compact design, reliable pointing stability, and repeatable beam characteristics from laser to laser, Dart delivers high-quality picosecond laser cutting and drilling even in tough industrial environments.

The laser is compatible with the portfolio of scan heads to maximise optical parameters and throughput whilst maintaining precision. The sales engineers may tailor solutions to the customers' applications and can provide complete sub-systems focussed on the customers' specific requirements.

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Particle measuring using lasers

Manufacturer: Laser Quantum.
Supply: Lasers "gem 532 nm" and "opus 532 nm" for industrial applications like particle measurement.
Background: In a semiconductor wafer fabrication process, particle measurement is used to ensure that chemical, cooling and cleaning fluids are free from contaminants. Liquid particle measuring is performed by specialist instrumentation that can be integrated into the production line. Such instruments are equipped with high power lasers that deliver a balance of high power and low noise in a compact, high reliability platform. *Laser Quantum* has a long heritage in developing lasers with just these features. Using patented high performance cavity technology, the lasers maintain constant low noise over long periods of time – one of the key characteristics in maintaining very low false positives within the particle measurement process.
Features: Ease of integration is a key design feature across all products of the manufacturer. Both "gem" and "opus"-families feature a small form factor, high wall plug electrical efficiency and deliver distinct benefits in thermal management. All enhanced by an advanced air cooling system enabling the lasers to be used in environments where water cooling is not permitted or feasible. The lasers feature an advanced integrated power feedback. Thus, the laser is able to intelligently maintain and optimize its own power levels in order to maintain beam specification with no power fluctuations, making them truly the laser of choice for high reliability, 24/7 system integrated applications.

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Image and surface analysis software

Manufacturer: Digital Surf.
Supply: Major new release of the "Mountains 9" software platform for image and surface analysis in microscopy and metrology. With version 9 comes a new branch of the software, "MountainsSpectral", for correlation and spectroscopy analysis, as well as several new optional modules, new file formats and many new features. New features include a new-look interface, surface texture analysis on freeform surfaces (shells) and analysis of multi-channel cubes of compositional data.
Features: The new version notably extends the platform in two directions: full three-dimensional data analysis and spectral analysis. As far as 3D data analysis is concerned, the addition of surface texture parameters on freeform surfaces now makes it possible to calculate roughness on any type of non-planar part, even on very complex shapes. New spectral analysis features provide solutions for correlative microscopy and the combining of chemical mapping and microscopic surface texture. Together, full-3D views and spectral mapping allow the visualization and analysis of multi-channel voxel cubes and I(V) spectroscopy data cubes. Three new modules also make their debut in the version 9 release: "Shell Topography" brings surface texture analysis to freeform surfaces (shells); "Chemical cubes" is designed for the visualization analysis of multi-channel cubes of compositional data; "IV Spectroscopy" allows SPM investigation of electrical surface properties including 3D visualization of datacubes and individual IV curve analysis (including CITS).

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Improving long-distance quantum communication

Dual band stabilization technique cancels the problem of temperature and strain fluctuations

The Cambridge Research Laboratory of Toshiba Europe recently announced the first successful demonstration of quantum communications over optical fibers exceeding six hundred kilometers in length. The breakthrough will enable long distance quantum-secured information transfer between metropolitan areas and is a major advance towards building the future Quantum Internet. This future global network of quantum computers will be connected by long distance quantum communication links. It is expected to allow the ultrafast solution of complex optimization problems in the cloud, a more accurate global timing system and highly secure communications across the globe. Several large government initiatives to build a quantum internet have been announced, for example in the US, EU and China.

One of the most difficult technological challenges in building the quantum internet is the problem of how to transmit quantum bits over long optical fibers. Small changes in the ambient conditions, such as temperature fluctuations, cause the fibers to expand and contract, thereby scrambling the fragile qubits, which are encoded as a phase delay of a weak optical pulse in the fiber.

Now, Toshiba has demonstrated record distances for quantum communications by introducing a novel dual band stabilization technique. This sends two optical reference signals, at different wavelengths, for minimizing the phase fluctuations on long fibers. The first wavelength is used to cancel the rapidly varying fluctuations, while the second wavelength, at the same wavelength as the optical qubits, is used for fine adjustment of the phase. After deploying these new techniques, Toshiba found it is possible to hold the optical phase of a quantum signal constant to within a fraction of a wavelength, with a precision of tens of nanometers, even after propagation through hundreds of kilometers of fiber. Without cancelling these fluctuations in real time, the fiber would expand and contract with temperature changes, scrambling the quantum information.

First demonstration of quantum communications over optical fibers exceeding 600 km in length. (Source: Toshiba)

The first application for dual band stabilization will be for long distance quantum key distribution (QKD). Commercial QKD systems are limited to around 100 – 200 km of fiber. In 2018, Toshiba proposed the twin field QKD protocol as a way to extend the distance, and tested its resilience to optical loss using short fibers and attenuators. By introducing the dual band stabilization technique, Toshiba has now implemented twin field QKD on long fibers and demonstrated QKD over 600 km, for the first time. “This is a very exciting result,” says Mirko Pittaluga. “With the new techniques we have developed, further extensions of the communication distance for QKD are still possible and our solutions can also be applied to other quantum communications protocols and applications”.

Andrew Shields, head of the quantum technology division at Toshiba Europe remarks, “QKD has been used to secure metropolitan area networks in recent years. This latest advance extends the maximum span of a quantum link, so that it is possible to connect cities across countries and continents, without using trusted intermediate nodes. Implemented along with Satellite QKD, it will allow us to build a global network for quantum secured communications.” Taro Shimada, corporate senior vice president and chief digital officer of Toshiba reflects, “With this success in quantum technology, Toshiba is willing to further expand its quantum business with rapid speed. Our vision is a platform for quantum information technology services, which will not only enable secure communication on a global scale, but also transformational technologies such as cloud-based quantum computing and distributed quantum sensing.”

The work was partially funded by the EU through the H2020 project, OpenQKD. The team is now engineering the proposed solutions to simplify their future adoption and deployment. This latest development follows the announcement last year that BT and Toshiba had installed the UK’s first industrial quantum-secure network. Transmitting data between the National Composites Centre (NCC) and the Centre for Modelling & Simulation (CFMS), Toshiba’s multiplexing compatibility allows the data and the quantum keys to be transmitted on the same fiber, eliminating the need for costly dedicated infrastructure for key distribution. The combined arrival of multiplexed QKD using existing infrastructure for shorter distances, alongside twin field QKD for longer distances, paves the way for a commercially viable global quantum-secure network.

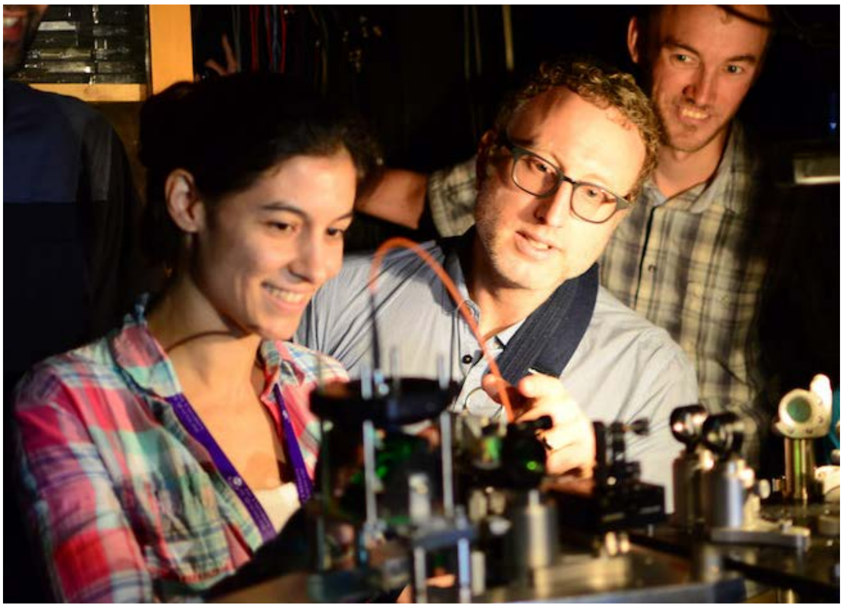
QKD allows users to securely exchange confidential information over an untrusted communication channel. It does that by distributing to the intended users a common secret key that can be used to encrypt, and thus protect, the information exchanged over the communication channel.

Reference: *M. Pittaluga* et al.: 600-km repeater-like quantum communications with dual-band stabilization, Nat. Phot. **15**, 530 (2021); DOI: 10.1038/s41566-021-00811-0

www.quantum.toshiba.co.uk

Prototype of a quantum microscope

Quantum entanglement provides 35 % improved clarity without destroying the living cell



Catxere Casacio, Warwick Bowen, and Lars Madsen (l. t. r.; source: U. Queensland)

University of Queensland researchers have created a quantum microscope that can reveal biological structures that would otherwise be impossible to see. This paves the way for applications in biotechnology, and could extend far beyond this into areas ranging from navigation to medical imaging. The microscope is powered by the science of quantum entanglement.

Warwick Bowen from UQ's Quantum Optics Lab said it was the first entanglement-based sensor with performance beyond the best possible existing technology. "This breakthrough will spark all sorts of new technologies – from better navigation systems to better MRI machines," he said. "Entanglement is thought to lie at the heart of a quantum revolution. This is the first proof of the paradigm-changing potential of entanglement for sensing," Bowen added.

A major success of the team's quantum microscope is its ability to catapult over a hard barrier in traditional light-based microscopy. "The best light microscopes use bright lasers that are billions of times brighter than the sun," Bowen said. "The quantum entanglement in our microscope provides 35 % improved clarity without destroying the cell, allowing us to see minute biological structures that would otherwise be invisible. The benefits are obvious – from a better understanding of living systems, to improved diagnostic technologies."

Bowen said there were potentially boundless opportunities for quantum entanglement in technology. "Entanglement is set to revolutionize computing, communication and sensing," he said. "The last piece in the puzzle was sensing, and we have now closed that gap. This opens the door for some wide-ranging technological revolutions", Bowen explained. (Source: U. Queensland)

Reference: *C. A. Casacio* et al.: Quantum-enhanced nonlinear microscopy, Nature **594**, 201 (2021); DOI: 10.1038/s41586-021-03528-w

https://equs.org

Quantum encryption goes out of the lab

Field trial shows simple QKD system works with existing telecommunication network.

In a new study, researchers have demonstrate an automated, easy-to-operate quantum key distribution (QKD) system using the fiber network in the city of Padua, Italy. The field test represents an important step toward implementing this highly secure quantum communication technology using the type of communication networks already in place in many regions around the world.

The researchers led by Paolo Villoresi and Giuseppe Vallone report that their simple system is stable over time and can generate quantum-secure cryptographic keys at sustained rates over a standard telecommunications infrastructure. "QKD systems usually require a complex stabilization system and additional dedicated synchronization hardware," said Marco Avesani from Università degli Studi di Padova. "We developed a complete QKD system that can be directly interfaced with standard telecom equipment and doesn't require additional hardware for synchronization."

To produce the quantum states required by QKD, the researchers developed a new encoder for manipulating the polarization of single photons. The encoder, which the researchers call iPOGNAC, provides a fixed and stable polarization reference that does not require frequent recalibration.

The researchers also developed a new synchronization algorithm, which they call Qubit4Sync, to synchronize the machines of the two QKD users. Rather than using dedicated additional hardware and an added frequency channel for synchronization, the new system uses software and the same optical signals being used for QKD. This makes the system smaller, cheaper, and easier to integrate into an existing optical network. (Source: OSA)

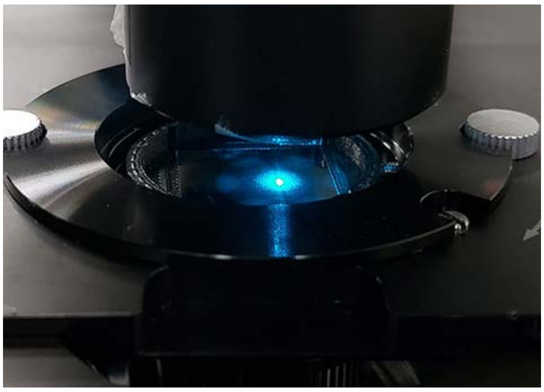
The entire transmitter for the new QKD system fits in a 19-inch rack enclosure. (Source: L. Calderaro, U. Padova)

Reference: *M. Avesani* et al.: Resource-effective quantum key distribution: a field trial in Padua city center, Opt. Lett. **46**, 2848 (2021); DOI: 10.1364/OL.422890

Light-shrinking material for higher resolution

New material turns a conventional light microscope into a super-resolution microscope

Electrical engineers at the University of California San Diego have developed a technology that improves the resolution of an ordinary light microscope so that it can be used to directly observe finer structures and details in living cells.



The metamaterial mounted on the stage of an inverted microscope. (Source: J. Zhao)

The technology turns a conventional light microscope into what is called a super-resolution microscope. It involves a specially engineered material that shortens the wavelength of light as it illuminates the sample – this shrunken light is what essentially enables the microscope to image in higher resolution.

"This material converts low resolution light to high resolution light," said Zhaowei Liu, a professor of electrical and computer engineering at UC San Diego. "It's very simple and easy to use. Just place a sample on the material, then put the whole thing under a normal microscope – no fancy modification needed." The work overcomes a big limitation of conventional light microscopes: low resolution. Light microscopes are useful for imaging live cells, but they cannot be used to see anything smaller. Conventional light microscopes have a resolution limit of 200 nanometers, meaning that any objects closer than this distance will not be observed as separate objects. And while there are more powerful tools out there such as electron microscopes, which have the resolution to see subcellular structures, they cannot be used to image living cells because the samples need to be placed inside a vacuum chamber.

"The major challenge is finding one technology that has very high resolution and is also safe for live cells," said Liu. The technology that Liu's team developed combines both features. With it, a conventional light microscope can be used to image live subcellular structures with a resolution of up to 40 nanometer. The technology consists of a microscope slide that's coated with a type of light-shrinking material called a hyperbolic metamaterial. It is made up of nanometers-thin alternating layers of silver and silica glass. As light passes through, its wavelengths shorten and scatter to generate a series of random high-resolution speckled patterns. When a sample is mounted on the slide, it is illuminated in different ways by this series of speckled light patterns. This creates a series of low resolution images, which are all captured and then pieced together by a reconstruction algorithm to produce a high resolution image.

The researchers tested their technology with a commercial inverted microscope. They were able to image fine features, such as actin filaments, in fluorescently labeled Cos-7 cells –features that are not clearly discernible using just the microscope itself. The technology also enabled the researchers to clearly distinguish tiny fluorescent beads and quantum dots that were spaced 40 to 80 nanometers apart. The super resolution technology has great potential for high speed operation, the researchers said. Their goal is to incorporate high speed, super resolution and low phototoxicity in one system for live cell imaging. Liu's team is now expanding the technology to do high resolution imaging in three-dimensional space. (Source: UCSD)

Reference: *Y. U. Lee* et al.: Metamaterial assisted illumination nanoscopy via random super-resolution speckles, Nat. Commun. 12, 1559 (2021); DOI: 10.1038/s41467-021-21835-8

www.zhaowei.us

A photonic twin of Michelangelo's David

Laser-scanned and 3D-printed art piece for Expo Dubai

A 3D printed replica of Michelangelo's famous David sculpture, reproduced with the use of scanning technology by Hexagon, was unveiled in May during a ceremony at the Italy Pavilion at Expo 2020 Dubai. The so-called David Twin will be the centerpiece of the pavilion's Theater of Memory.

3D-printed replica of Michelangelo's David, reproduced with the use of scanning technology (Source: Hexagon)

The project to create the replica posed numerous challenges, not least due to the scale of the original, which stands at over seven metres tall and weighs more than five tons. Scanning this iconic sculpture took two people 10 days to complete. Two Hexagon technologies, an AICON StereoScan neo structured light scanner and a Leica Absolute Tracker with handheld scanner, were used to ensure optimum accuracy while managing the scale of the challenge.

The mix of these two technologies was critical to achieve the best result; the laser tracker, which is typically used to measure precision aerospace components, is able to give high accuracy across large areas and the structured light scanner is able to achieve even higher resolution when focused on small areas. This instrument was used for the particularly detailed elements of the sculpture such as the face and hands. By combining these technologies, the team was able to achieve the optimum compromise of scale and resolution.

Nevertheless, there were a number of additional challenges to overcome. For example, an 80cm distance was required between the scanner and the statue to achieve optimum detail. This was particularly tricky when trying to capture intricate parts. Additionally, given the height of the David, the scanners had to be mounted on a stair and raised, after which the team would analyze the picture to check for resolution and accuracy, and repeat if necessary.

Following David's appearance at the Expo, the digital twin created by the scanning process will be analyzed to derive additional learnings. The extraordinary detail of the data reveals, for example, the effects of acid rain and dust, and even traces of the different tools used to create it. This information can be used by experts and restorers to preserve the David, and other iconic art pieces, by anticipating and preventing degradation.

It is also recognized that there may be opportunities for future, more accurate scans of the David and other iconic art pieces. This latest project follows a similar one completed by Stanford University in 1999, which took one month and 22 people to achieve a lower resolution scan. As technology advances it's hoped that an even higher level of detail can be achieved.

"Scanning David presented a number of challenges," says Cesare Cassani, automation technologies and portable systems manager, Hexagon's Manufacturing Intelligence division. "Not only was the scale enormous, but the time constraints were also tight, and we had to overcome a number of obstacles as we went along. Specific parts such as the inside of the hands, and underneath the bent arm, for example, proved particularly challenging, as well as capturing all the dents and imperfections that the David has incurred over the years."

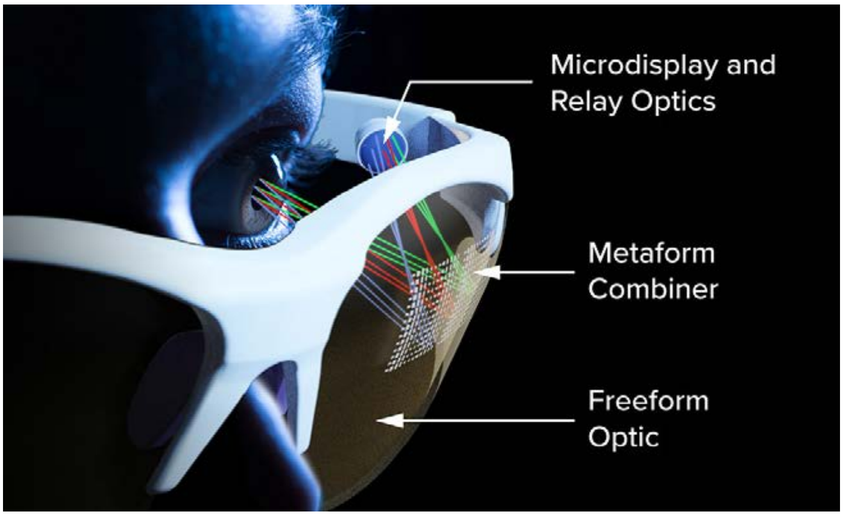
www.hexagonmi.com

A new way to make VR glasses

Combining freeform optics and a metasurface to avoid the effect of bug eyes

Consumers are looking for AR/VR glasses that are compact and easy to wear, delivering high-quality imagery with socially acceptable optics that don't look like 'bug eyes'. University of Rochester researchers at the Institute of Optics have come up with a novel technology to deliver those attributes with maximum effect. They combined freeform optics with a nanophotonic metasurface.

The metasurface is a veritable forest of tiny, silver, nanoscale structures on a thin metallic film that conforms, in this advance, to the freeform shape of the optics – realizing a new optical component the researchers call a metaform. The metaform is able to defy the conventional laws of reflection, gathering the visible light rays entering an AR/VR eyepiece from all directions, and redirecting them directly into the human eye.



A metaform is a new optical component to create the next generation of AR/VR headsets and eyewear. (Source: M. Osadciw, U. Rochester)

Nick Vamivakas, a professor of quantum optics and quantum physics, likened the nanoscale structures to small-scale radio antennas. "When we actuate the device and illuminate it with the right wavelength, all of these antennas start oscillating, radiating a new light that delivers the image we want downstream." "Writing metasurfaces on freeform optics is creating an entirely new type of optical component," says Jannick Rolland, director of the Center for Freeform Optics. "This kind of optical component can be applied to any mirrors or lenses, so we are already finding applications in other types of components such as sensors and mobile cameras."

The goal is to direct the visible light entering the AR/VR glasses to the eye. The new device uses a freespace optical combiner to help do that. However, when the combiner is part of freeform optics that curve around the head to conform to an eyeglass format, not all of the light is directed to the eye. Freeform optics alone cannot solve this specific challenge. That is why the researchers had to leverage a metasurface to build a new optical component.

"Integrating these two technologies, freeform and metasurfaces, understanding how both of them interact with light, and leveraging that to get a good image was a major challenge," says Daniel Nikolov, an optical engineer in Rolland's research group. Another obstacle was bridging "from macroscale to nanoscale," Rolland says. The actual focusing device measures about 2.5 mm across. But even that is 10,000 × larger than the smallest of the nanostructures imprinted on the freeform optic.

"From a design standpoint, that meant changing the shape of the freeform lens and distributing the nanostructures on the lens in a way that the two of them work in synergy, so you get an optical device with a good optical performance," Nikolov says. This required a way to circumvent the inability to directly specify metasurfaces in optical design software. In fact, different software programs were used to achieve an integrated metaform device.

The researchers used a JEOL electron-beam lithography (EBL) machine at the University of Michigan's Lurie Nanofabrication Facility.

Reference: *D. K. Nikolov* et al.: Metaform optics: Bridging nanophotonics and freeform optics, Sci. Adv. 7, eabe5112 (2021); DOI: 10.1126/sciadv.abe5112

www.hajim.rochester.edu/optics

An industry first VCSEL line beam transmitter for LiDAR

Focuslight introduces module for automotive applications

Focuslight Technologies, a global provider of high power diode lasers and micro optics, has announced the FocusFlux LX01 VCSEL line beam transmitter module. An industry first, the transmitter combines a multijunction, high peak power 905 nm VCSEL with unique optical beam shaping technology to produce a very uniform line beam (>80 %) with FA divergence of <0.15° (horizontal) and SA divergence of 23° (vertical FOV, customizable). The slow axis divergence angle and energy distribution within the FOV can be customized on request.


FocusFlux LX01 (Source: Focuslight)

"Compared with line beam transmitter modules based on EEL edge-emitting laser, the FocusFlux LX01 transmitter has core advantages of high-reliability, smaller wavelength temperature shift coefficient, lower sealing requirements, and overall lower cost at high volumes," said Kenneth Ferree, VP of sales and marketing at Focuslight Technologies. "With an APD array or the new SPAD/SIPM linear array as the lidar detector, the resulting lidar system can achieve high beam density, high resolution, and longer detection range. It is a preferred light source for next-generation line beam scanning lidar."

The FocusFlux LX01 line beam transmitter is the newest addition to Focuslight's lidar TX L line beam product line. The overall dimensions are 50.9 × 47.9 × 78.9 mm. The optical power is 200 W, which can be used for new project optical performance evaluation and concept or prototype development.

Part of the Focuslight FocusFlux Series, the FocusFlux LX01 line beam transmitter is designed with special materials and an assembly process that meets automotive grade reliability, production, and quality requirements. It is able to lase as usual under high temperature (+80 °C) and low temperature (-40 °C), as defined and required by automotive standards. This enables users to comply with automotive requirements at a system level. Focuslight is IATF 16949 certified and can provide mass production services and technical solutions for automotive customers.

Further reading: *D. Hauschild & D. Braam*: Accurate beam shapes for efficient lidar: Defined light distribution and wide-angle illumination requirements in automotive light detection and ranging, PhotonicsViews 18(3), June/July 2021; DOI: 10.1002/phvs.202100044

www.focuslight.com

Scalable manufacturing of integrated frequency combs

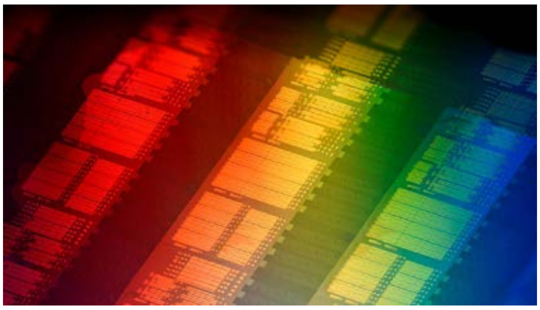
CMOS technology allows wafer-scale manufacturing of chip-scale optical frequency combs

Optical frequency combs consist of light frequencies made of equidistant laser lines. They have already revolutionized the fields of frequency metrology, timing and spectroscopy. The discovery of soliton microcombs by Tobias Kippenberg's lab at the Swiss Federal Institute of Technology (EPFL) in the past decade has enabled frequency combs to be generated on chip. In this scheme, a single-frequency laser is converted into ultrashort pulses, the dissipative Kerr solitons. Soliton microcombs are chip-scale frequency combs that are compact, consume low power, and exhibit broad bandwidth. Combined with the large spacing of comb teeth, microcombs are uniquely suited for a wide variety of applications, such as terabit-per-second coherent communication in data centers, astronomical spectrometer calibration for exoplanet searches and neuromorphic computing, optical atomic clocks, absolute frequency synthesis, and parallel coherent lidar.

Yet, one outstanding challenge is the integration of laser sources. While microcombs are generated on-chip via parametric frequency conversion, the pump lasers are typically off-chip and bulky. Integrating microcombs and lasers on the same chip can enable high-volume production of soliton microcombs using well-established CMOS techniques developed for silicon photonics, however this has been an outstanding challenge for the past decade. For the nonlinear optical microresonators, where soliton microcombs are formed, silicon nitride has emerged as the leading platform due to its ultralow loss, wide transparency window from visible to mid-infrared, absence of two-photon absorption, and high power-handling capability. But achieving ultralow-loss Si3N4 microresonators is still insufficient for high-volume production of chip-scale soliton microcombs, as co-integration of chip-scale driving lasers is required.

Fifteen years ago, John Bowers's lab at University of California, Santa Barbara, pioneered a method for integrating semiconductor lasers onto a silicon wafer. Since silicon has an indirect bandgap and cannot emit light, scientists bond indium phosphide semiconductors on silicon wafers to form laser gain sections. This heterogeneous integration laser technology has now been widely deployed for optical interconnects to replace the copper-wire ones that linked servers at data centers. This transformative laser technology has already been commercialized, and Intel ships millions of transceiver products per year. The two labs now demonstrate the first heterogenous integration of ultralow-loss Si_3N_4 photonic integrated circuits and semiconductor lasers through wafer-scale CMOS techniques.

The method is mainly based on multiple wafer bonding of silicon and indium phosphide onto the Si_3N_4 substrate. Distributed feedback (DFB) lasers are fabricated on the silicon and indium phosphide layers. The single-frequency output from one DFB laser is delivered to a Si_3N_4 microresonator underneath, where the DFB laser seeds soliton microcomb formation and creates tens of new frequency lines. This wafer-scale heterogeneous process can produce more than a thousand chip-scale soliton microcomb devices from a single 100-mm diameter wafer, lending itself to commercial-level manufacturing. Each device is entirely electrically controlled. Importantly, the production level can be further scaled up to the industry standard 200 or 300-mm-diameter substrates. "Our heterogenous fabrication technology combines the three mainstream integrated photonics platforms, namely silicon, inidium phosphate and Si_3N_4, and can pave the way for large-volume, low-cost manufacturing of chip-based frequency combs for next-generation high-capacity transceivers, data centers, sensing and metrology," says EPFL's Junqiu Liu.



Areal of hundreds of semiconductor lasers and silicon nitride microresonators. (Source: C. Xiang, UCSB)

Reference: *C. Xiang* et al.: Laser soliton microcombs heterogeneously integrated on silicon, Science **373**, 99 (2021); DOI: 10.1126/science.abh2076

www.epfl.ch/labs/lmsc/qct/
https://optoelectronics.ece.ucsb.edu

Microlight3D selected for "cool" project

Manufacturer of two-photon polymerization systems helps concrete buildings to cool down naturally

Microlight3D, a specialty manufacturer of high-resolution microscale 2D and 3D printing systems, has been awarded FET-Open European funding to develop microstructured concrete that will transform a building's capacity to cool down itself. This nanotechnology project, led by "Photonic Metaconcrete with Infrared Radiative Cooling capacity for Large Energy Savings" (MIRACLE) – a European consortium of TU Darmstadt (Germany), Universidad Publica de Navarra (Pamplona, Spain), Fundacion Tecnalia Research & Innovation (San Sebastian, Spain), Katholieke Universiteit Leuven (Belgium), Politecnico di Torino (Italy) and Microlight3D – has the potential to revolutionize the construction industry and considerably lower the impact concrete buildings have on the environment.

"By using microstructured concrete, buildings will be able to cool down naturally and thereby reduce the 'urban heat islands' that build up in cities during summer heatwaves, which can make these spaces unbearable," said Denis Barbier, co-founder & CEO of Microlight3D. "This structural building material, which can cool down by itself, will also reduce the energy consumption used for air conditioning and benefit the climate by lowering CO_2 emissions." The consortium selected Microlight3D for the ability of its 3D microprinting technology to create microstructures at ultrahigh resolution, in materials rigid enough that they can be used as molds for concrete and create microtopographies.

The first microstructured concrete sample (Source: Microlight3D)

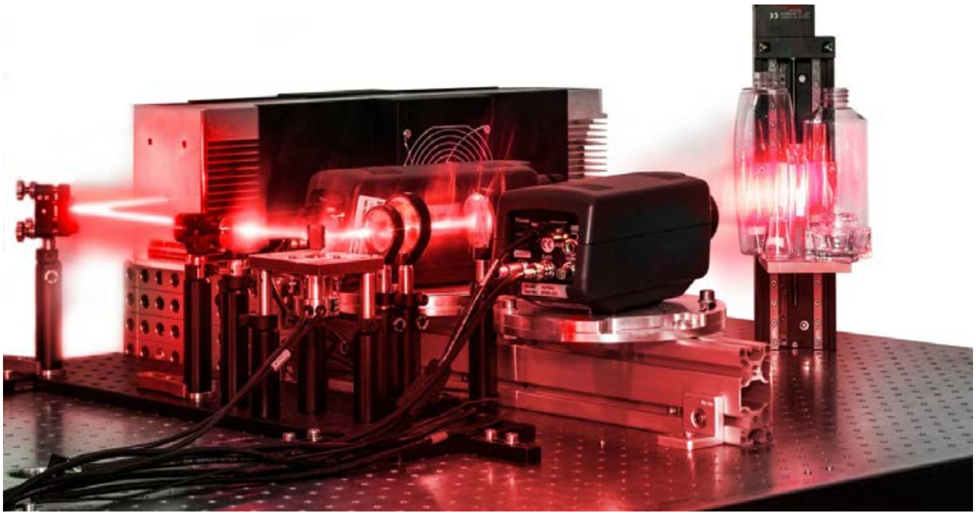
In this project, Microlight3D will use its two-photon polymerization technology to create microstructures which will be used as molds for concrete. This will allow steel microfibers to be inserted inside the microtopography variations created at the surface. In doing so, the concrete will be transformed into a photonic metamaterial, converting the solar heat into infrared wavelengths that are then re-emitted. The 'photonic metaconcrete' is thereby able to expel heat from buildings into outer space without consuming any extra energy.

"Microlight3D is proud to participate in a project aimed at creating cities that are more pleasant to live in and more respectful of the environment," said Philippe Paliard, co-founder and head of users and applications at Microlight3D. "It is exciting to see that our two-photon polymerization technology can offer solutions to, and have a real impact on, combatting environmental issues."

www.microlight.fr

Glass and transparent objects become visible to machines

New 3D sensor scans transparent objects – conceivable applications in robotics



Laboratory setup to demonstrate the MWIR 3D measuring principle (Source: Fh. IOF)

A new measurement method for 3D shape acquisition has been developed by researchers at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF. With their "MWIR-3D sensor", they can scan objects three-dimensionally, regardless of whether they are made of transparent plastic or glass. Even objects with shiny metallic or jet-black surfaces can be detected without any difficulties. Combining different materials is also no problem for the new 3D infrared sensor. In the field of 3D sensor technology, this degree of flexibility in the properties of the object is a first.

"Glass360Dgree": First MWIR 3D system for checking Glasele in optics manufacturing (Source: Fh. IOF)

Until now, if you wanted to measure reflective, transparent or black surfaces accurately with conventional 3D scanners, you first had to treat their surface for this purpose. This means that the objects were temporarily coated with varnish for the measurement. After the scan, this usually had to be removed again at great effort. This invention will make this impractical and time-consuming treatment of the object superfluous in the future. Due to the size of the measuring field as well as the resolution and speed, the method is also suitable for quality control in production processes or for applications in automation.

This is possible because researchers at the Fraunhofer Institute in Jena have succeeded in making thermal radiation usable for 3D measurement. The researchers therefore refer to this method as "3D sensing in the thermal infrared range". At the heart of the system is a high-energy CO_2 laser with which the objects are irradiated.

Using special lenses for high power densities, the laser beam is expanded into a line that vertically illuminates the entire object. For a high-resolution measurement result, this line is moved over the object in a specially coordinated sequence. The energy of the laser light is absorbed by the measured object and partially re-emitted.

Combination of thermography and triangulation

Two thermal imaging cameras analyze the thermal signature left by the narrow and intense infrared line on the object from two different perspectives. Afterwards, a software developed in-house calculates spatial pixels from the information of the two viewing angles and merges them into the exact dimensions of the measured object.

The thermal energy introduced for the 3D analysis is so low that the object is not damaged. The temperature difference between heated and non-heated surfaces is typically less than 3 °C. For this reason, the method is also suitable for sensitive materials.

"By switching from a full-surface thermal pattern to a narrow thermal strip, we have succeeded in advancing the technology in such a way that we can meet the requirements placed on a 3D sensor in industrial use," emphasizes Martin Landmann, a researcher of the imaging and sensing department at Fraunhofer IOF. Together with his team and a group of researchers of the innovation alliance "3Dsensation", he has been working on the system since 2017.

"With adaptive mirror optics, we have succeeded in focusing the power of the laser on a much smaller surface, thus providing the necessary contrast for the thermal imaging cameras much faster. Only this made it possible to achieve an accuracy of less than 10 µm for the 3D coordinates with a field of view width of 160 mm," he explains.

Following the successful scientific demonstration of the new measurement method, the researchers are now working intensively to make the measurement principle ready for the market: "For us, it is now a matter of transferring the system from the laboratory to practical use," explains Landmann.

In addition to optimizing the method for various measurement scenarios and applying it in industrial plants, the team led by Landmann and group leader Dr Stefan Heist is working on a system for use in robotics. This system focuses on transforming the laboratory setup into a prototype that is as compact and robust as possible. In this way, robots can be enabled to recognize and grasp transparent objects.

The first application-oriented system that uses this MWIR 3D measuring principle is "Glass360Dgree". The system is specially designed for checking glass elements in optics production and is also intended to be used by research partners to test how the measurement process can be integrated into a variety of robotic processes.

www.iof.fraunhofer.de

Christoph Garbe becomes a member of the EMVA board of directors

Tribute to Gabriele Jansen after two decades of engagement

Dr Christoph Garbe

The members of the EMVA have elected Dr Christoph Garbe, CEO at HD Vision Systems, to the association's board of directors with a clear majority. The physicist with a doctorate and habilitation in computer vision will now represent the EMVA externally together with his board colleagues. "I am grateful for the trust that the members of the EMVA have placed in me. In the next three years, I would therefore like to fully commit myself to their interests," Garbe rejoices.

He would like to use his term of office to bring new developments in Machine Vision even more strongly into industrial application. To this end, he would like to build bridges to new technologies: Garbe plans to make the EMVA more accessible to young companies and startups through various formats. This forms a missing link between leading international research institutions as a breading ground for innovation, often spawning startups, and established innovative companies within the EMVA. Activities to this end will bring significant added benefit to all members and lay the ground for continued growth of the EMVA.

Within the umbrella of collaboration, innovation will also to be strengthened by various training programs, especially on new trends and technologies. At the same time, Garbe would also like to advocate that machine vision should not only be understood as sensors and components, but that the software side should be strengthened further. "Today's challenging requirements in the industrial manufacturing landscape paired with the immense performance of today's Vision Controllers make applications a central component of modern Machine Vision. In order to continue to provide the market with excellent solutions, a perfect interplay between precise sensors and high-performance software is indispensable," says Dr Garbe.

For the upcoming three-year term, the new board consists of nine members, namely

- Arnaud Destruels, Sony Europe BV (Image Sensing Solutions)
- Arndt Bake, Basler
- Prof Dr Bernd Jähne, Heidelberg Collaboratory for Image Processing of Heidelberg University
- Dr Chris Yates, Vision Ventures
- Dr Christoph Garbe, HD Vision Systems
- Dr Dirk Berndt, Fraunhofer Institute for Factory Operation and Automation IFF
- Dr Kai-Udo Modrich, Zeiss Inline Inspection & Metrology
- Dr. Marco Diani, iMage S
- Dr. Ronald Mueller, Vision Markets

The new elected board of directors will have its constituent in-person meeting as soon as possible and by then vote on the roles of EMVA president; vice president and treasurer amongst its members.

In a series of emotional farewell video statements many leaders of machine vision players gave their tribute to Gabriele Jansen who chose not to candidate for another term. Gabriele Jansen has been founding member of the EMVA and board member since the association was established in 2003, making her the longest serving board member in the association's history. From 2003 to 2009 Gabriele Jansen served as EMVA president.

Also stepping down from the EMVA board are Jochem Herrmann who acted as EMVA president from 2015 – 2019; Jean Caron, who was EMVA board member and treasurer from 2015 – 2021; and Michel Ollivier, who was EMVA vice president from 2015 – 2021.

www.emva.org
www.hdvisionsystems.com

ASAM launches open source tooling platform

To support use of ASAM OpenX standards for the validation of autonomous driving functions

ASAM e.V., the Association for Standardization of Automation and Measuring Systems, has set up an open source platform to host tools from member companies that support the implementation and use of ASAM OpenX standards. BMW has already contributed an ALKS scenario interpretation based on ASAM OpenSCENARIO® and ASAM OpenDRIVE®.

These standards describe an interface as well as static and dynamic content for driving and traffic simulators and are used to validate autonomous driving functions. Since the transfer, the user base has multiplied and the standards are further developed at a rapid pace. ASAM has identified a great need for tools to support the implementation, training and use of these standards. For that purpose, ASAM has implemented an open source platform to host and share ASAM compatible tooling that help to better understand the standards and facilitate their usage. "Our goal is to bring about a platform and community that directly supports our standards and makes using or adopting them as easy as possible," says Benjamin Engel, Global Technology Manager at ASAM e.V.

The ASAM Open Source Platform is hosted on GitHub (https://github.com/asam-oss). The tools posted there are subject to the responsibility and license terms of the providing company. They are accessible to all companies free of charge and can be used independently of an ASAM membership. First tools are already available:

A first tool is already available: BMW contributes test scenarios from the ALKS (Automated Lane Keeping System) control that it has implemented based on ASAM OpenSCENARIO and ASAM OpenDRIVE. The derived XML files are executable with all standard-compliant simulators.

www.asam.net

EPIC collaborates with IEEE

European Photonics Industry Consortium forms partnership with IEEE Photonics Society

The IEEE Photonics Society, a vital part of the world's largest technical professional organization dedicated to advancing technology, and the European Photonics Industry Consortium (EPIC), a membership-led, non-profit industry association that promotes the sustainable development of organizations working in the field of photonics, have announced that their associations have entered into a multiyear agreement to promote joint activities, cross-disciplinary technical dissemination and cooperative programs between membership bodies.

Resulting from the societies' agreement, both organizations seek to enhance engineers, physicists, scientists, industry professionals, and students access to industry-relevant training and continuing education opportunities in the related fields of the organizations' scopes, ranging from LED lighting, photovoltaic solar energy, photonics integrated circuits, optical components to lasers, sensors, imaging, displays, projectors, optic fibers, and other photonic related technologies.

"EPIC being the largest photonics industry association in the world, I am very much looking forward to partnering with the most important academic knowledge base in the world of photonics. Together we will be able to achieve great things to the benefit of the Photonics community!", stated Carlos Lee, EPIC director general.

EPIC collaborates with IEEE (Source: EPIC)

EPIC offers a vibrant photonics ecosystem and strong network acting as a catalyst and facilitator for technological and commercial advancement throughout Europe. The IEEE Photonics Society will benefit from EPIC's relationship with start-ups, SMEs, large companies, research organizations and other stakeholders that accelerate technological advancements and reach emerging photonics markets.

The IEEE will provide EPIC's members access to highly cited publications, conferences, academics, and eligibility for annual awards contributing to advancements in technology. There are over 400,000 IEEE members in over 160 countries, more than sixty percent of whom are from outside the United States. As one of 39 technical societies of the IEEE, the Photonics Society will provide avenues for local and international engagement with innovators the field and the next generation of photonics engineers and scientists of tomorrow. The partnership will facilitate collaboration across the IEEE, launch initiatives, and recommendations for the development of products and services that meet the needs of industry.

"The Photonic Society's partnership with EPIC is a fantastic opportunity to work collectively to advance the missions of both organizations. It will directly support the efforts of the Society's Industry Engagement Committee to develop programs and activities that enhance the experience and engagement of Photonics Society members and the wider community working in industry," stated Dalma Novak, IEEE technical activities division X director and IEEE Photonics society industry engagement committee chair.

The Society's industry engagement committee, led by Novak, will directly steer services between the parties' agreement as well as encourage entrepreneurship initiatives and increase the elevation of industry members within relevant IEEE leadership positions. (Source: EPIC)

www.epic-assoc.com

www.ieee.org

EPIC hires Alan Nemeš as marketing manager

The European Photonics Industry Consortium is growing fast and it is now the largest industry association in the world. To support the marketing needs of its more than 700 members, EPIC hired Alan Nemeš as marketing manager, who will start mid-August.

He will take care of the marketing for the EU projects and support overall EPIC marketing activities. Alan has studied at the University of Ss. Cyril and Methodius with a focus on marketing and media. From then on his work was focused on building a career in marketing, starting in small agencies, then larger ones and later transforming to the client side.

From the most relevant positions, he would mention head of marketing for Preciosa Lighting and marketing manager for Svoboda & Williams real estate. He is very passionate about his work and keeps his attention to every detail of it.


Alan Nemeš (Source: EPIC)

www.epic-assoc.com

Structuring the capital market in photonics

EPIC introduces the 'Solactive EPIC Core Photonics Index'

European Photonics Venture Forum 2018 in Barcelona supported by EPIC

Always looking for ways to support the photonics community and find benefits for its members, EPIC – the European Photonics Industry Consortium – now proudly presents the 'Solactive EPIC Core Photonics Index'. This is the first photonics index on the stock market representing photonics companies. The index is a tool to assess the ROI of the photonics industry, a sector that historically has had share value increase at an average of 25.9 % CAGR.

"If you wanted to invest in photonics, then you needed to choose the individual companies to select. With this index, you are investing in 58 companies which means that you reduce volatility and, consequently, risk", says Carlos Lee, director general at EPIC. "We will build on this index to ensure several benefits for both the industry and the members of EPIC. Every individual who wants to surf the photonics wave will soon be able to invest in a new financial product that tracks this index."

EPIC PHOTONICS INDEX

The firm contracted for this index is Frankfurt-based Solactive, which has been developing tailor-made and multi-asset class index solutions for index-linked investment products since 2007. EPIC has developed the methodology of which companies should be included as it embarks on contributing to the structuring of a photonics capital market to support the creation and growth of the companies.

"With this new photonics index, we will inform financial investors and highlight markets and applications potential", says Antonio Raspa, innovation manager at EPIC. "The impact will result in greater recognition and credibility of the photonics sector. Plus, our members will have greater access to the financial investment community, will be better informed on the various options to raise money, and will benefit from the increased activities related to business / growth.

Launching the Solactive EPIC Core Photonics Index, is just one of the latest activities that the association has initiated in the financial community. Every year EPIC organizes investor roadshows and events, and chairs investor-related events, like at the European Photonics Venture Forum in 2018. We engage with networks of business angels, early investors, scale-ups, banks, and corporate investors. EPIC is seemingly becoming the largest funnel for investing into photonics, another great privilege for its members as they gain priority access to technology scouting through investments and acquisitions.

For more information about the Solactive EPIC Core Photonics Index, please visit www.photonics-index.org. To find out more about the EPIC Investor activities, contact innovation manager Antonio Raspa at antonio.raspa@epic-assoc.com.

www.epic-assoc.com

Upcoming EPIC events:

- 06 September 2021, 16:00 CEST EPIC Online Technology Meeting on New Developments FMCW LiDAR
- 13 September 2021, 15:00 CEST EPIC Online Technology Meeting on Spectroscopy and Imaging for Process Monitoring
- 20 September 2021, 15:00 CEST EPIC Online Technology Meeting on Laser Ablation and Laser Cleaning
- 22 September 2021, 15:00 CEST EPIC Online Technology Meeting on Mid-IR Technologies for Environmental Monitoring (in cooperation with MidIR Alliance)
- 27 September 2021, 15:00 CEST EPIC Online Technology Meeting on Head-Up Displays: from 2D to AR
- 04 October 2021, 15:00 CEST EPIC Online Technology Meeting on Automation of Packaging and Testing of Photonic Integrated Circuits
- 06 October 2021, 15:00 CEST EPIC Online Quantum Technology Meeting on Atomic Clocks and Network Synchronization
- 11 October 2021, 15:00 CEST EPIC Online Technology Meeting on Laser Vision Correction
- 18 October 2021, 15:00 CEST EPIC Online Technology Meeting on Graphene Technology and Applications
- 25 October 2021, 15:00 CEST EPIC Online Technology Meeting on Low Light Camera Technology and Applications

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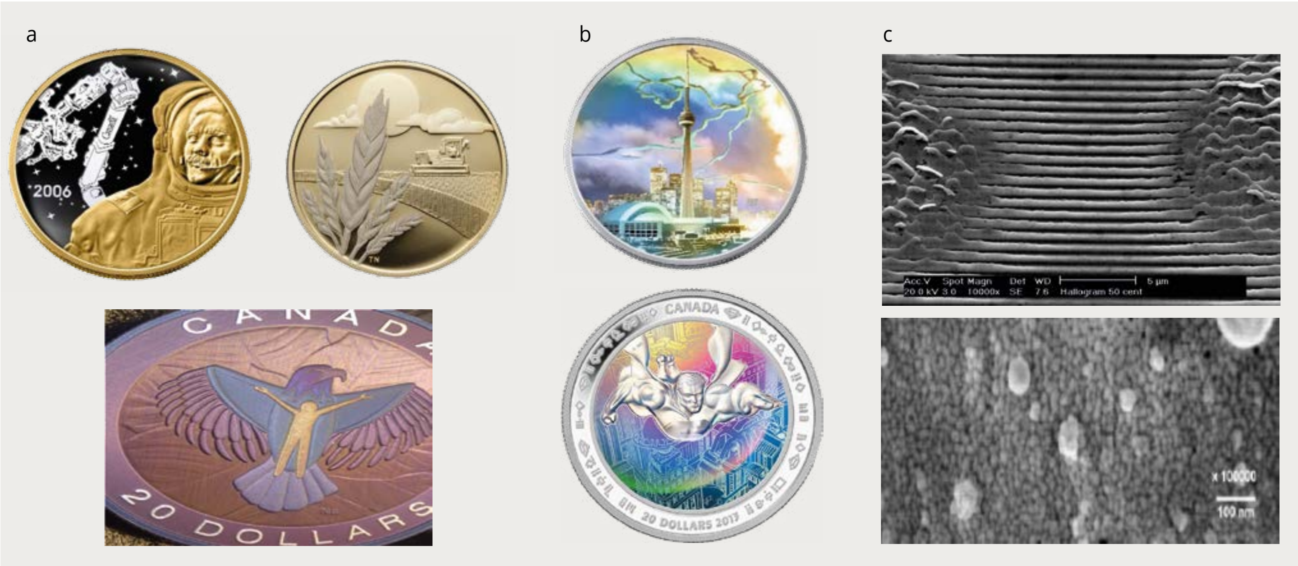
New challenges for the laser micromachining community

How the minting industry and other application fields are motivating their supply chain in photonics to strive for even better performance

Francesca Moglia



Source: Royal Canadian Mint

▲Fig. 1 Different applications of laser micromachining in the minting industry. Pure black, grey shades and color effects on coins (a) and holographic effects created by laser surface structuring on the mold (b). The panels in (c) show microscopic views of examples of the surface structures.

In one of EPIC's recent meetings about laser micromachining, lively discussions took place about how the supply chain can support machine builders to reach new frontiers in applications. Laser-based surface functionalization is still a hot topic and laser micro-drilling in glass has achieved very high throughput. We report here on the wish-lists of end-users, service and machine providers, including interesting opportunities to collaborate with them.

Laser micromachining does not have a distinct definition, but here it is intended in the broader sense to mean all material processes where short and ultrashort-pulsed (USP) lasers are employed for the definition of features in the micro and sub-micrometer scale. These processes can affect either the surface characteristics (e.g. surface functionalization) or the bulk material (e.g. micro-drilling, micro-turning, even micro-welding). Judging by the experience within the framework of the European Photonics Industry Consortium (EPIC), the interest of the full supply chain in new developments and the application of laser micromachining is tremendous.

The minting industry has put a variety of applications and technical challenges to the experts from laser manufacturing and integration. The Royal Canadian Mint (RCM) is an established representative from this industry, dealing with the manufacturing of Canadian and foreign coins as well as numismatic collectable coins and medallions. They have already been applying laser technology for a few years, especially in four main product categories. The first is the application of special visual effects on golden collector coins without compromising the purity of 9999 or even 99999 gold. With laser surface texturing, it is possible to avoid the use of alloys and to imprint nano-scaled features directly on the golden surface of the coins to influence their optical properties, resulting in pure black (complete absorbance), grey shades or different color effects (see Fig. 1a). The same strategy can also be applied on the dies used to stamp the coins, for example to transfer 2D/3D holographic effects directly onto golden or silver coins (see Fig. 1b). The third application represents the core manufacturing process of RCM where laser processing is used to generate different grades of high-relief effects through deep laser engraving onto dies or directly onto the medals. Die frosting is mainly performed through laser processing on the die surface and can show different aesthetic-contrast effects.

Fig. 2 Example of the micromachining capabilities of the Lasea company. Deep black texturing macro (left) and microscopic views (right) (Source: Lasea)

These optical features were achieved by creating micro or nanostructures on either the coin or the die surface using laser micromachining (see **Fig. 1c**). The fourth application supports anti-counterfeting or anticounterfeiting to be consistent and security features and is based on all the technologies mentioned so far to generate special unique security features on coins combined with an exclusive digital encryption technique.

RCM has recognized the potential of laser technologies and, for this reason, they are looking forward to receiving support from the laser-micromachining community with a few challenges they are facing at the moment. For example, laser technology could support them in improving the surface quality of the coining dies, which can currently suffer from microcracks or oxide formation that compromise the effectiveness of subsequent processing, such as protective coating deposition to extend the lifetime of the dies and the quality of the coins. Another wish of RCM would be to implement special advanced surface features on the coins. They would largely benefit from further dynamic and animation effects in both grayscale and color, applicable on different channels beyond the previously mentioned holographic effects. Anticounterfeiting is also an application area where RCM believes laser micromachining experts could help in enhancing the current measures to add advanced security features. Currently, laser marking is used to create a well but randomly-defined surface pattern combined with encrypted coding technology. The so-called 'well-defined randomness' gives rise to uniqueness. RCM is exploring different technologies and aiming to create the next-generation of security features. Laser processing is under investigation as well and could be further integrated and combined once new and interesting advancements have been shown.

Finally, the minting industry could rely on laser surface texturing to provide advanced features of coins, such as superhydrophobic or antibacterial features which, in this pandemic period, are gaining more and more relevance in a very broad range of industries.

Who could help RCM and the minting industry in general with all these challenges? The photonics community at present can definitely provide some solutions and assist them with future ad-hoc developments. For example, femtosecond lasers are still unexplored by RCM because the related business case has so far been limited by the higher cost and lower throughput of fs vs. ps lasers, despite the better surface finishing. Also motivated by the improvements gained by moving from ns to ps lasers, they are now open to reconsidering the fs lasers business case.

The photonics industry also has to bear in mind that, for RCM, the laser process in combination with vision systems has already proven to be more efficient overall than the manufacturing processes with traditional methods such as sandblasting for the frosting effects, which may require some prior manual masking. So the requirements of the minting industry are about further improvements of surface quality and more exciting and novel surface features … let's engage with them!

The Microrelleus company is a workshop and service provider already familiar with the needs of the minting industry and, with sufficient studies and testing, they could apply their acquired experience with different kinds of steel materials. Surface processing obtained with 5-axis machines integrating USP lasers is their core business. They aim to achieve the industrialization of in-mold over a flat or 3D shape. Their main applications are micro-structuring, for the lighting industry for example to achieve homogeneous light diffusion or homogeneous light intensity of a light guide or freeform optics to create different functional light effects. Functional texturing, like hydrophobicity or self-lubricating textures, is also part of their service portfolio. The processing of molds that are then used to manufacture the

Organization

EPIC – European Photonics Industry Consortium

EPIC is the world-leading photonics industry association representing more than 700 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, pavilions at exhibitions.

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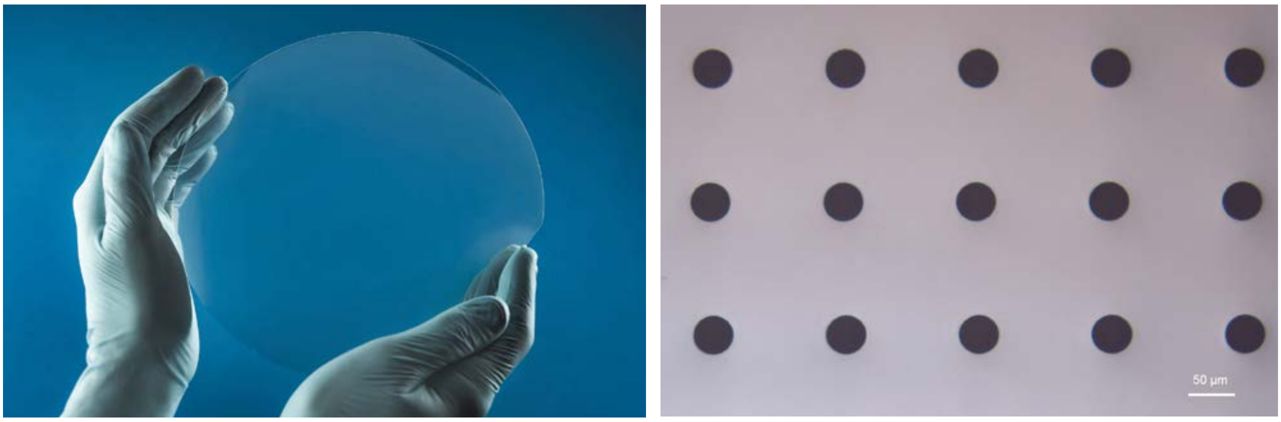

Fig. 3 Example of the micromachining capabilities of the Workshop of Photonics company: 3,000,000 holes in an 8-inch, 500 µm-thick fused silica wafer; macro (left) and microscopic (right) views. (Source: Workshop of Photonics)

final pieces for their customers avoids the throughput required from the laser machines directly processing the final pieces, which has either to be faster than competing technologies or potentially be combined with laser-free manufacturing processes. The durability and sensitivity of fine surface texturing is still a challenge that the full supply chain should commit to improving.

One of the companies ensuring that fs-lasers can best demonstrate their performance by integrating them into reliable systems is Lasea. At high average powers, the residual thermal effects become significant and can degrade the quality of processing and optical components, posing specific new challenges. Therefore new treatment strategies must be applied, based on laser application and specifications: laser beam shaping, high-speed scanning, parallel processing, or a combination thereof. Lasea's micromachining workstations are manufactured following new trends coming from state-of-the-art R&D for applications ranging from luxury goods to the medical and electronics industries, and also include the deep-black texturing needed by the minting industry (see example in Fig. 2). Lasea is supporting further eco-design solutions that can reduce polluting processes based on the laser functionalization of surfaces, and the EU-funded LAMpAS project is one of them. In this collaboration, eight partners (Technische Universitaet Dresden, Trumpf, Lasea, Next Scan Technology, Bosch, EPIC, New Infrared Technologies and B/S/H) are working together to build a machine based on an ultrashort-pulsed laser that is able to deliver high-throughput surface processing at 1 to 5 m^2/min, giving special properties to the surfaces such as super-hydrophobicity and anti-bacterial features without additional coating or chemicals. A 1.5 kW ps laser, high-resolution multibeam processing, high-speed beam deflection and an in-line monitoring camera are planned to be integrated into a complete, robust workstation. A possible future customer of LAMpAS could therefore be the minting industry.

From the experience learned in this and other EU-funded initiatives, experts from Fraunhofer IWS and industry recently founded the start-up Fusion Bionic to commercialize an interference-based technology for high-speed surface functionalization using USP lasers. They provide solutions such as compact modules for direct laser interference patterning (DLIP), for example to be integrated with lasers at different wavelengths and adapted to generate variable surface feature sizes between 200 nm and 30 µm on various materials. These could be metals, polymers, glass or ceramics for surface functionalization such as anti-icing, efficient de-icing, and darkening (also of glass). Working with interference implies the need for high spatial and temporal-coherence laser sources, which the founders are always eager to test.

Another approach to laser surface texturing at high rates is Holo/Or's newly developed diffractive laser-induced texturing (DLITe) beam splitter, which was demonstrated earlier this year in co-operation with HiLASE center. In the demo, a DLITe 51 × 51 mm^2 splitter was used with a Perla laser system (HiLASE, Czech Republic), a standard F-theta and scanner setup to pattern stainless steel. Each shot patterned 1 × 1 mm^2 with >2500 microcraters, at 20 µm hatch distance. Scanning the fields achieved a process rate of 58 cm^2/min.

Green wavelengths are often more suitable for the surface processing of glass than the standard 1 µm. A spin-off company called Biomimetic from the Foundation of Research and Technology Hellas (FORTH) is concentrating on laser nano-texturing of glass with USP-lasers to enhance properties such as anti-glare, anti-reflection and anti-fogging. It is important for them to understand the properties of different kinds of glass just as much as for companies dedicated to the full spectrum of micromachining of glass. One of these companies is Workshop of Photonics (WOP). They are both machine builders, integrating USP lasers in complete workstations, and also service providers for medium-volume production that has to be delivered fast. Glass processing is their key competence. Their proprietary technology allows ultrafast (up to 1200 holes/s) drilling using fs lasers into glass wafers, which are then chemically etched (see Fig. 3). They can also provide support by applying their experience with laser-based plastic and optical-polymer cutting and drilling, topics that are raising a lot of interest in different companies. These include Wielandts UPMT, a start-up dedicated to developing innovative technologies related to lens arrays, working mostly on monolithic multicavity molds and multilens array masters.

There is also interest in the energy sector in the processing of glass, extending to other more exotic materials. At General Atomics, they have developed expertise in fine micromachining, supplying the fusion research program in the USA. Activities such as drilling 200 µm deep, 5 µm large holes through beryllium shells and processing difficult materials such as MgO-glass and

Fig. 4 Micromachining capabilities of Oxford Lasers. Images clockwise from top right: laser milling microfluidics in borosilicate glass, laser welding of dissimilar materials – BK7 glass welded to aluminium, laser surface texturing for controlled wettability (hydrophobicity), thin-film patterning – indium tin oxide on PET, surface texturing of stainless-steel channels, laser drilling 90 µm holes in polyimide, laser drilling 50 µm square holes in silicon nitride, laser drilling a 35 µm hole in molybdenum. Center image: an Oxford Lasers C Series industrial micromachining tool (Source: Oxford Lasers)

depleted uranium to shape and contour them are among their tasks. Generally, they pursue good surface finishes and micron-level control of various surface features. In particular, forming micron-level features such as fine steps or fine waves on glass and other optical materials and maintaining the original properties of an optical surface are among their interests and areas in which they are eager to collaborate.

The Oxford Lasers company is one of the leaders among the providers of both laser micromachining tools and subcontract services, covering a large spectrum of applications (see **Fig. 4**). For example, using USP lasers they are capable of directly welding glass to dissimilar materials e.g. glass to metals, silicon or welding to glass itself, without any additional interlayers such as optical adhesives. This can be extremely beneficial in the manufacture of complex electro-optical devices for defense/aerospace /photonics applications as well as for OLED lighting, offering truly hermetic sealing and precise optical bonding. The previously mentioned laser-based surface functionalization is among their strengths too. Oxford Lasers is also keen to apply cutting-edge technology and has expectations of its supply chain as well as a strong wish for partnership. Some of their requirements are for diode-pumped solid-state lasers with better dynamic performance and a high process speed, industrial-grade, deep-UV, cost-efficient lasers (delivering the 4^{th}, 5^{th} and even 6^{th} harmonics of Nd:YAG-based lasers to avoid excimer-based solutions), five-axis precession heads, tailored beam shaping in the temporal and spatial domain and artificial intelligence (AI) for laser-micromachining solutions.

An EU-funded initiative supporting the development and application of laser micromachining also involving AI already exists and is called PULSATE. Its aim is to connect the many digital innovation hubs in Europe with expertise in laser-based manufacturing technologies and to reach all of the SMEs who want to join a digital manufacturing and Industry 4.0 environment, and who see laser as a key enabling technology but are unable to implement it due to the lack of testing capabilities. This initiative will support SMEs through cascade funding and also through its unique support program created by technology and business experts from consortium partners. Interested companies can apply to the program through two kinds of open calls: Technology Transfer Experiments (launches in July 2022) and Adopter User Cases (launches in March 2022).

Beam shaping techniques have been flourishing and diversifying lately due to the increasing demands of different laser-based technologies. Many providers such as Asphericon with a comprehensive and aspheric range of laser beam processing elements, Suss MicroOptics offering refractive and diffractive micro-optics for any standard and challenging beam shape, Cailabs light-shaping experts for high-power applications with their multiplane light conversion technology, Optimax branding their capabilities in aspheres, cylinders, prisms, spheres and freeforms, and Qiova with their innovative digital beam shaping solutions, are among the right addresses for system integrators wanting to improve the performance of their laser micromachining workstations.

A company that can help a customer to understand if all the laser micromachining technologies are suitable for their particular application is Optoprim. They are experts in product distribution, providing the added value of a laboratory for testing equipment that includes a Light Conversion fs laser at 40 W with a harmonic generator, an Alio monolithic XY stage, a Scanlab scanner head, and software from Direct Machining Control to control laser machining processes such as machine vision.

A suggestion for machine builders is also to integrate laser diagnostics directly into their workstations. USP laser manufacturers such as Coherent, Fluence, Ekspla, EdgeWave and Light Conversion already provide industrial-grade solutions for reliable and versatile integration that could be facilitated if a diagnostic system could also be implemented and put in a closed-loop for active control. Companies such as Laserpoint and Optocraft are among the laser-diagnostic experts. Laserpoint can provide specific instruments to control USP parameters such as pulse energy up to a repetition rate in the order of megahertz, while Optocraft are experts in developing metrology tools such as their Shack-Hartmann wavefront sensors for complex laser systems, which are able to deliver the laser phase and intensity information in real time, potentially to be implemented with active control by laser stations for beam quality and alignment.

Talking about process monitoring, hyperspectral imaging snapshot cameras have recently been used to implement online inspection systems based on diffractometry to monitor surfaces textured by rapid USP lasers. The EU-funded MULTIPLE initiative could provide tools for laser micromachining because it is developing cost-effective multimodal monitoring solutions, bringing cutting-edge organic electronics-based sensors, snapshot hyperspectral filters and dual-aperture imaging to deliver spectrometers and camera cores in a broad VIS/SWIR range, complemented with laser-based sensors in the mid-IR. The full system will be IoT native by combining the hardware with the cloud, big data, and deep learning for agile development and orchestration of complex AI-based models to provide overall monitoring, control and optimization of production lines.

*

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Family Firm

EPIC Interview with David Mackey, CTO at Mbryonics and PakPIC

Jose Pozo

The company led by David Mackey and his siblings is a leading developer and manufacturer of free space optical communications systems, optical ground terminals and adaptive optical systems.

Source all images: Mbryonics

With a passion for aircraft from a young age, David graduated from the University of Limerick with a BEng in aeronautical engineering in 2009. The degree included a placement with Airbus in Toulouse, where he worked on acoustics data analysis and installing flight test systems for the A380 during certification tests. On graduating, his experience at Airbus together with an increasing interest in physics led to a PhD in applied optics at the National University of Ireland.

He was fortunate to have a good supervisor who allowed him the freedom to be creative in solving problems of applying micro-electromechanical adaptive optics systems for free space communications. The focus was on the development of field-programmable gate array real-time, closed and open loop control using novel integrated optics wavefront sensing techniques.

As he recalls: “The learning experience of building the full system and solving real problems was one of the most creative times of my educational life – once you’ve solved one really hard problem, you realize you can apply your brain to solve pretty much any challenges that fall in front of you.”

Mbryonics

Towards the end of his PhD, David began working with his sister Ruth who, after also completing a PhD in adaptive optics at the National University of Ireland, had set up a consultancy advising on optical systems.

By 2014, three things had become apparent: first, satellite optical communication was emerging as a real commercial opportunity; second, between them, David and Ruth had the necessary technological expertise to exploit that opportunity; third, that with the business acumen from their brother John, they would be able to set up a successful commercial venture. Accordingly, the three siblings co-founded Mbryonics in 2014 with John as CEO, Ruth as chief scientific officer and David as CTO.

The idea of the company, as its name suggests, would be to take ‘embryonic’ i.e. immature technologies and to apply science and engineering to get them market-ready for the next era of satellite and wireless communications networks. Specifically, they would use their expertise in areas such as optomechanics, freeform and active optics, optoelectronic system design engineering and application-specific photonic integrated circuits to design space optical instruments and systems for harsh ground and space environments.

Company development

They bootstrapped for the first three years until 2018, when they were awarded their first contract with the European Space Agency to develop a very challenging adaptive optics system to handle the very high data rates necessary for the satellite uplinks of the ScyLight program.

Since then, there have been various other ESA technology development projects, such as ProtoBIX, in which Mbryonics is developing a novel silicon photonic integrated circuit platform and advanced co-packaging to handle the on-board terabit-per-second processing requirements of next generation satellites.

There have also been two advanced process developments for the low-cost volume manufacturing of ultralight freeform optics. The first of these is an in-line, automated metrology system using a combination of advanced sensors and imaging systems to enable the automated manufacturing of freeform optics for their satellite laser communications terminal. The second is the development of an advanced engineering and manufacturing solution to enable the volume production of low-cost, ultralightweight mirrors based on freeform optics for use in their highly miniaturized, satellite optical communication terminals.

Finally, under AFFRESCO, the company is developing a PIC-based, free

Co-packaged optics – silicon photonics transceiver design for high speed serial interconnects being developed through ESA ProtoBIX activity.

form, satellite optical terminal to enable robust fiber coupling for both networking and multiplexing and also to allow the terminal to be used in quantum key distribution links.

Mbryonics' collaboration with ESA has been crucial because taking on these difficult and demanding challenges for space has served as an excellent testing ground to find solutions that can be applied elsewhere. For example, their silicon PIC platform and advanced co-packaging solution has attracted interest from the terrestrial data communications sector, particularly for co-packed optics (CPO), and potentially for next generation, hyperscale data centers. Similarly, solutions for the volume production of low-cost freeform optics and ultralightweight mirrors have applications in aviation, automotive, and AR/VR verticals.

Revenues have grown annually since 2014 and Mbryonics has become one of Europe's leading developers and manufacturers of free space optical communications systems, optical ground terminals and adaptive optical systems in the field of satellite communications.

PakPIC

A major priority for Mbryonics has been to develop PIC packaging skills. In the early days, EU packaging pilot lines like PIXAPP and JEPPIX had not yet been established, and in the absence of services from the supply chain, they found they were having to do most of the packaging themselves.

As a solution, they set up a subsidiary, PakPIC, to take care of their own and their customers' packaging requirements for integrated photonics. Many of their customers were approaching design houses first and then thinking about packaging. But as David explains, a better approach is to think about packaging at the outset and design the PIC in accordance with what's feasible within current packaging technologies. It is basically a co-design problem in that it is impossible to optimize PIC design and packaging without understanding the whole assembly process.

Testing goes hand-in-hand with packaging, and designing the PIC for testing is the key to having lower testing costs. One of Mbryonics' key selling points is that they always design their PICs with testing in mind. For example, their silicon-based PICs with integrated lasers can be tested at wafer level by probing with electronics, and the detectors on the chip can be used to calibrate each one.

PakPIC now provides packaging services as well as design processes for customers who want to control the entire value chain and do their own packaging in-house. The subsidiary now has a workforce of 17 with enough scalability for future growth.

Future challenges and opportunities

Standards: One of the main challenges is the lack of standards, not only for PICs but also for the service requirements, the drivers, and the modulation formats and, as David points out, it's very hard to plan a technology roadmap that is not set in stone. However, there is some positive movement in this area coming from the standards being set by big players such as Microsoft and Facebook, who both have a good grasp of the technology requirements.

Microwave photonics: Microwave photonics is rapidly being adopted by the space industry as an enabler for the next generation of satellites. The move from a niche to a mainstream technology is due to the fact that, while electronics can compete quite well at some of the lower frequencies, photonics offers advantages for the much higher frequencies required by the space industry that just are not achievable with other technologies. Similarly, from the terrestrial perspective, microwave photonics will be needed for the higher frequency requirements of 5G and 6G.

However, from the power perspective, a major challenge with higher optical frequencies is the cost of amplifying them, due to the fact that they need to be directly converted to an analog electrical signal.

Automotive: Although it is probably still more than five years away before advanced photonics systems like lidar become mainstream, the automotive industry has two main challenges. The first is a lack of standards; the second is that whereas the space market has semi-large production and extremely high reliability, automotive needs to combine mass production with high reliability, which is far more problematic.

Metrology: As David explains, what has really been essential, once again, is an understanding of the manufacturing challenges and various processes that require different levels of resolution. For example, one of the main challenges of using magnetic hydrological polishing to obtain ultrahigh quality, free form surfaces is the accuracy required in measuring the mid-spatial frequencies.

Freeform composite mirror for optical terminal – manufacturing, assembly, integration, and test require novel metrology techniques to measure the figure error and mid-spatial frequencies to optimize manufacturing and alignment.

If you started again, what would you do differently?

"I don't know how I would have done it without the support of my brother and sister. Starting any company is emotionally and technically very challenging and having people you can trust right beside you is essential, so I have absolutely no regrets about being part of a family company."

"One thing we could have done differently is to seek investment at some point because the early years were extremely tough. If we had raised finance, it would have been much easier, and we would probably be further along the path. On the other hand, the advantage of having managed to retain one hundred percent of the company means we can continue to make ethical commercial choices, in that investors might have pushed us into some ethically questionable areas like weapon systems for the military where the returns are very high."

What is your advice for the next generation of entrepreneurs?

"Most CTOs in the photonics industry typically come from a physics background, but coming from an engineering background, I had an intuitive knowledge of how to engineer something and make it into a viable product. So for those in the academia sphere, I would recommend getting out of your comfort zone and doing something that will stretch you, like prototyping something, while also paying attention to the engineering processes and the processes that will be required to manufacture it."

"Once you show yourself that you can solve some hard engineering problems, you will realize that you can overcome whatever challenges come up on the technology roadmap that you're going to follow."

Author

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

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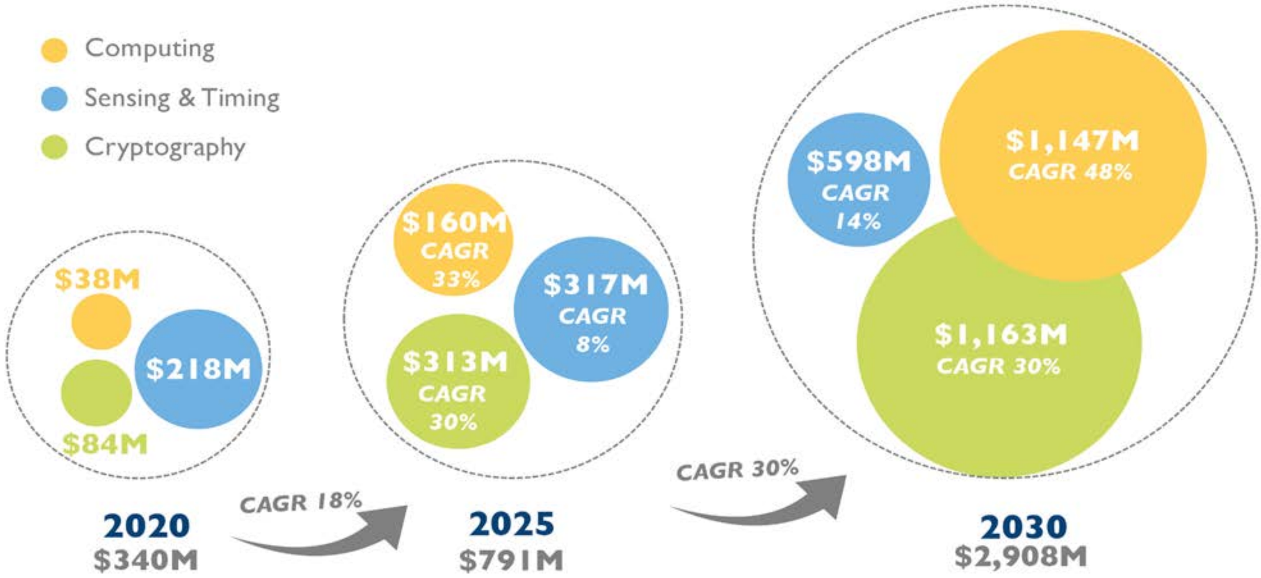
Quantum technologies: the market is growing

Although still a distant business, industrial interest in quantum continues



Source all images: Yole

2020 – 2030 market forecast for quantum technologies [1]

The total market for quantum technologies (computing, cryptography, sensing) will grow to US$ 2.9 billion in 2030. Yole forecasts 18 % and 30 % CAGR for 2020 – 2025 and 2020 – 2030, respectively.The three main market segments, quantum computing, quantum sensing / timing, and cryptography, will grow nicely between 2020 and 2030 to reach US$ 1,147 million, 598 million, and 1,163 million, respectively.

Application insights

Pharmaceutical is today attracting most of the attention for quantum computing. However, it will take many years – maybe twenty to thirty – before quantum is extensively used in medical and pharma applications.

Quantum computing will be ready to be used in five tto ten years for drug development (when there is already an identified drug candidate). For drug discovery, it will be ready in ten to twenty-plus years.

Following the adoption of quantum in pharmaceutical, other applications may jump on the train, too: energy, chemistry, transportation, banks, and finance could adopt quantum computing in ten or more years.

Supply chain

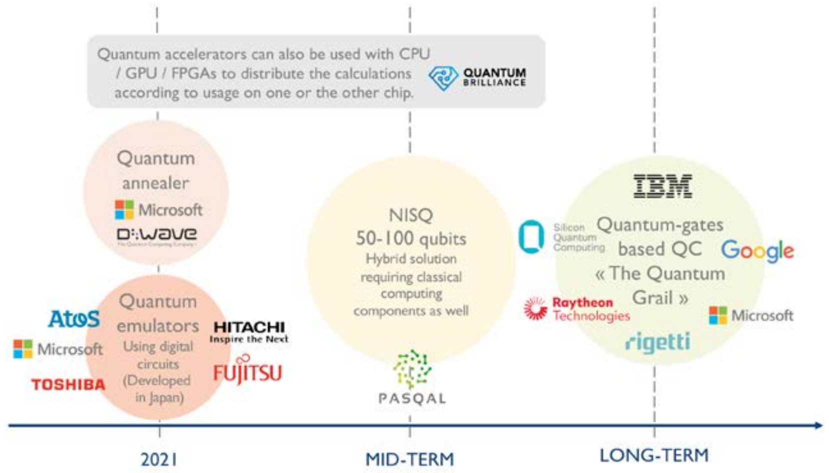
Since 2012, investors have shown interest in start-ups in quantum. And 2020 was particularly active for investments. Since 2012, almost US$ 2 B (including computing, software, cryptography, and sensors) have been invested in about eighty start-ups, with companies developing hardware receiving the largest share (60+ %).

Largest investments are in North America: PsiQuantum (photonic quantum processor), D-Wave (superconducting qubits), IonQ (trapped ions), Rigetti. Europe also has a quantum champion with IDQ in Switzerland.

“Quantum technology covers a wide range of applications addressing key industrial simulation and optimization challenges.” asserts Dr Eric Mounier, director of market research at Yole Développement (Yole). He adds: “These span chemicals / materials research, logistics, financial services, healthcare, life science, manufacturing and defense, drug discovery, protein structure prediction, investment risk analysis, feedstock management, vehicle routing, and network optimization. It is also a critical national issue for many countries as it addresses secure communications and database management linked to national security.”

For more than twenty years, Yole has developed its semiconductor activities by enlarging step by step its expertise in technical innovations and disruptions. Through this development, the company has grown with dedicated activities focused on a wide range of emerging technologies, including quantum computing, quantum sensing, metamaterials, wet-ware, neuromorphic, and more.

Released in June, the Quantum Technologies 2021 report includes market trends and forecasts, supply chain, technology trends, technical insights and analyses, take-aways, and outlook.



2021 quantum computer roadmap [1]

This study delivers an in-depth understanding of the ecosystem and leading players' strategies and enables a thorough understanding of the value chain, infrastructure, and players in quantum technologies and the quantum computing market.

What are the economic and technological challenges of quantum technologies? What are the key drivers? What will the market look like in 2030? Who are the companies to watch, and what innovative solutions are they working on?

As analyzed by Yole's team in the new Quantum Technologies 2021 report, quantum computing is still subject to technological and timing uncertainty, but investments continue. Medical and pharma applications are interesting, promising markets, but it seems that inorganic markets are "simpler" to address than medical markets for quantum technologies in the short term. In the next decade(s), extensive R&D will continue to define qubit solutions, quantum computer architectures, software, and business models. The supply chain will consolidate as well, and we could soon see the first acquisitions. Cryptography, sensing, and timing are already existing markets and will continue to grow. QKD could experience a market boost with 5G. The total value for quantum technologies, including computing, cryptography, and sensing, will grow from about $ 340 M in 2020 to $ 2.9 B in 2030. Quantum as a service (QaaS) will be 65 % of the total.

There is a long road before companies realize a universal quantum gate-based computer. Today, only one company – D Wave in Canada – is manufacturing and shipping quantum annealers. Although they use 2,000 to 5,000 qubits, these Ising machines are today restricted to optimization problems. Quantum emulators are another topic, one where Japan is strongly involved. The next step will be to develop 'noisy intermediate-scale quantum' (NISQ) machines with fifty to hundred logical qubits. Then the holy grail will be to develop a universal quantum computer with a minimum of hundred logical qubits, corresponding to 100,000 physical qubits.

Recently, another approach has emerged with the development of quantum accelerators. These will be used in conjunction with CPUs and GPUs or FPGAs in high-performance computers. Calculations will be distributed according to usage on one or the other chip, quantum or non-quantum. This is a mid-term approach to the use of hybrid quantum computers using both semiconductor logic chips and quantum accelerators with well-defined and distinct roles.

As part of its products and services, Yole's team offers a collection of reports covering such technologies. A detailed description of these reports is available on i-Micronews.com in the Reports section.

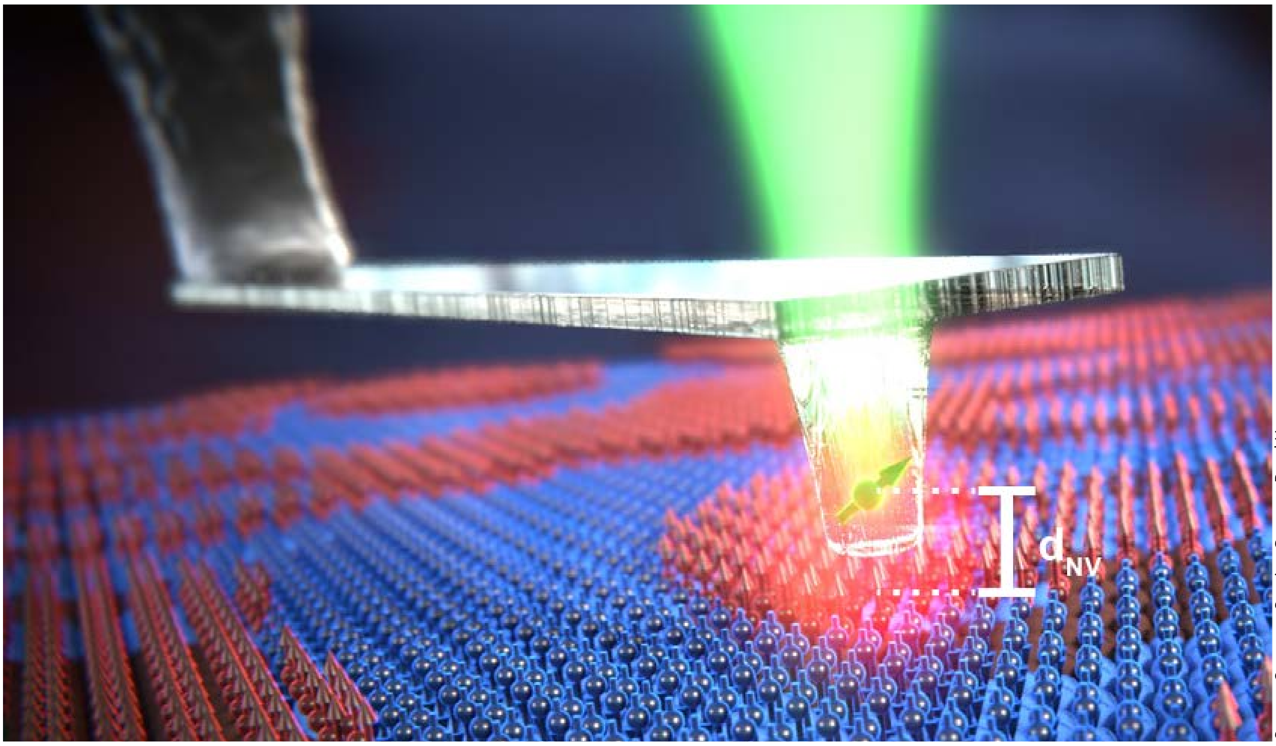
www.yole.fr

[1] Quantum Technologies 2021 report, Yole Développement, 2021, https://www.i-micronews.com/products/quantum-technologies-2021/

Technology leaps in quantum sensing

Advances in nano magnetometry using tailored electronics and fast-switchable lasers

Niklas Waasem, Helmut Fedder, and Patrick Maletinsky



Taking advantage of quantum effects has enabled the so-called first quantum revolution in the 20th century for technologies such as nuclear magnetic resonance spectroscopy, magnetic resonance imaging, and the development of transistors, LEDs, solar panels, and lasers.

▲ Nanoscale quantum sensors based on single spins in diamond: artist rendering of an all-diamond tip containing a single electron spin quantum sensor at its apex. The spin scans at a height of d_{NV} ~20 nm over a sample surface, where d_{NV} defines the ultimate imaging resolution of the approach. (Source: Basel U.)

Today, amid the second quantum revolution new sensing schemes offer higher sensitivities and better resolution thanks to the possibility to detect and control individual quantum states in microscopic systems like atoms, quantum dots, or color centers. Emerging quantum sensing techniques could lead to the improvement of sensing technologies ranging from quantum gravitometers and accurate atomic clocks to low-noise quantum-interference microscopy and ultimately find commercial uses in gyroscopes for self-driving cars, or brain-machine interfacing via magnetic field sensing.

As quantum sensing technology has matured over recent years, one of the contending techniques for commercially developed systems is based on nanoscale magnetometry with nitrogen vacancy (NV) centers in diamond. These centers act as optically addressable, highly sensitive quantum sensors which are highly miniaturized and localized to atomic length scales. Employing a scanning-probe approach with one NV center at the tip of an atomic force microscope (AFM) cantilever allows measuring magnetic fields with a spatial resolution on the nanometer scale and an extreme measurement accuracy.

Irrespective of which quantum sensing technology prevails, current solutions rely on the availability of state-of-the art components. Efforts towards commercialization drive improvement of the techniques for capturing or cooling these quantum centers and techniques for initializing, manipulating, and reading out single quantum states. This in turn drives the development of new lasers and electronics as well as miniaturization and innovative ways to allow mass production. Here we give an overview of the current proposed solu-

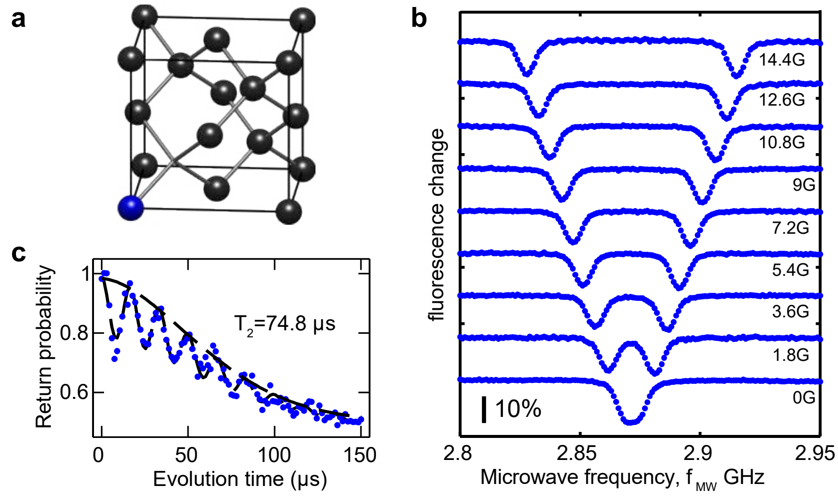


Fig. 1 The basics of NV center spins in diamond: crystal structure of the NV center (a), optically detected electron spin resonance, which forms the basis for most magnetometry applications (b), spin-coherence decay measurements (c), the typically long NV spin coherence times can be exploited to further enhance magnetic-field sensitivities of NVs. (Source: Basel U.)

tions for quantum sensors based on NV center magnetometry.

Nanoscale quantum magnetometry

Over the last decade, single electron spins in diamond have been established as nanoscale quantum sensors that exhibit excellent sensitivity and nanoscale resolution for imaging and sensing of magnetic fields and other quantities, such as electric fields or temperature [1]. Spins couple naturally to magnetic fields through the Zeeman effect. They can exhibit long quantum coherence times that can be exploited to yield excellent magnetic field sensitivities. Lastly, spins can be localized to atomic length scales that, in turn, enables imaging with nanoscale resolution. These quantum sensors can measure magnetic fields, and thus, electric currents with an unprecedented sensitivity and spatial resolution. Applications include determining magnetic structures on surfaces of multiferroic or antiferromagnetic materials or mapping high-frequency currents (GHz) flowing in electronic circuits.

Nitrogen vacancy (NV) centers in diamond have been recently identified as suitable candidates because the point defect provides an isolated spin state which can be manipulated using microwaves. These combined properties allow for optical detection of magnetic spin resonance (ODMR) at the level of individual NV electronic spins (Fig. 1). Magnetometry based on NV center spins measures the energy shifts — or, equivalently, shifts in the quantum-mechanical phase – that a spin experiences in the presence of a magnetic field. These ODMR traces represent the simplest method of implementation of such single-spin magnetometry, where the splitting between the observed ODMR resonances is directly proportional to the magnetic field the NV spin experiences.

To exploit these attractive properties for nanoscale quantum sensing, the NV sensor needs to be brought in close proximity to a sensing target, ideally just a few nanometers. The most flexible approach applies a scanning probe geometry, which scans the NV and sample with respect to each other for imaging. Today, the most robust and sensitive implementation of such scanning NV magnetometry is achieved by using diamond nanopillars that contain individual NV centers at their tip as scanning probes (Fig. 2). These diamond tips allow for detection of single electron spins by stray-field imaging at resolutions around 20 nm. This approach, originally conceived in 2012 [2], has since been refined [3] to the extent that commercial solutions are available today from companies such as the Swiss startup Qnami AG.

New approach to quantum sensing

A typical quantum sensing experiment starts by initializing the NV center's electron spin with a laser pulse lasting

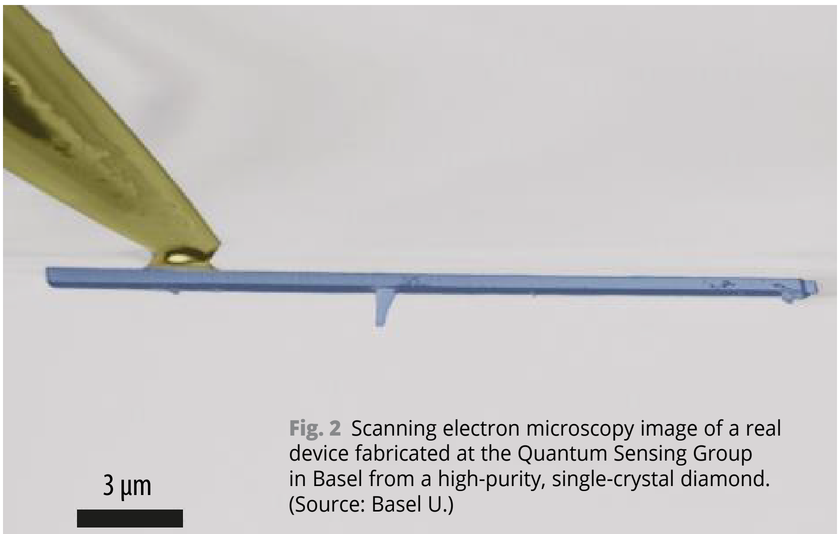


Fig. 2 Scanning electron microscopy image of a real device fabricated at the Quantum Sensing Group in Basel from a high-purity, single-crystal diamond. (Source: Basel U.)

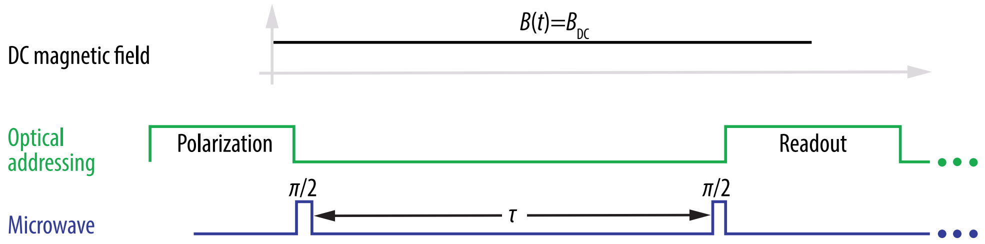


Fig. 3 Typical NV magnetometry sequences using a Ramsey pulse sequence on the NV spin. Optical excitation is used to initialize and measure the NV spin. (Source: Basel U.)

a few microseconds. The laser is typically operating in a wavelength range 510 – 560 nm which excites the NV center and populates a 'bright' electron spin state that leads to strong fluorescence at around 638 nm when excited. By subsequently applying a microwave pulse, it is possible to flip the spin to a secondary 'darker' state that shows less fluorescence. The spin-state after microwave exposure is read-out with a secondary laser pulse. The spin flip occurs when the microwave frequency matches the energy difference between the two states. As this energy difference depends on the magnetic field around the NV center, it is possible to determine the magnetic field by measuring at what microwave frequency the flipping to the darker state occurs, i.e. when the fluorescence is lowered (see Figs. 1b and 3). By applying elaborate sequences of microwave pulses of varying on/off times, so-called 'sensing protocols', it is possible to maximize measurement resolution and to also assess other parameters than the magnetic field, such as electric field strengths and temperature.

This approach requires strong microwave fields at the NV center position, which are achieved most efficiently by placing a thin wire in its vicinity. Control of the electron spin is implemented with a microwave synthesizer that is switched on and off via a high-isolation switch. The rise and fall times of the switches should last no more than a few nanoseconds – a limit imposed by the typically achievable Rabi frequencies for the atomic transition (which can reach several tens of MHz).

Traditionally, pulse sequences were described as bit strings, where one bit is consumed per sample clock tick. This approach requires a large sample memory and results in long instrument upload times. More recent methods use run length encoding to describe pulse sequences, wherein each pulse is described by an integer number that encodes its duration in clock ticks. For the sparse pulse sequences typical in quantum sensing protocols, this encoding improves upload time and greatly facilitates instrument programming. A typical quantum sensing experiment repeats the measurement sequence many times and the accumulated photon count encodes the probability of the spin state of the final measurement.

Most quantum sensing experiments proceed with a parameter sweep of the interrogation time, which is often equivalent to the interpulse spacing in the sensing sequence [4]. In such cases, one sensing measurement consists of a set of pulse sequences. Companies such as Swabian Instruments have been able to apply modern single-photon counting approaches to enable fast on-the-fly processing of single-photon detection events in a flexible fashion. Such approaches eliminate common hardware limitations, such as limited histogram range and bin numbers, and greatly facilitate the implementation of novel quantum sensing schemes.

Compact fast modulated lasers

The optical initialization and the readout sequences of the spin state of the NV-centers requires precisely tailored light pulses within the excitation spectrum of NV-centers. Other important parameters are listed in Table 1.

Some quantum-sensing applications also require the ability to generate pulse trains with arbitrary on/off times and excellent intensity stability and repeatability. Until recently, the most common approach to generate such laser pulses involved the combination of a 532 nm continuous-wave laser with a double-path acousto-optical modulator (AOM). However, these laser+AOM setups are difficult to align, bulky, expensive, sensitive to shocks, and require a large or active heatsink. Since 2018, diode lasers at 515 nm with direct intensity modulation have offered an alternative solution for use in lab setups and commercial systems.

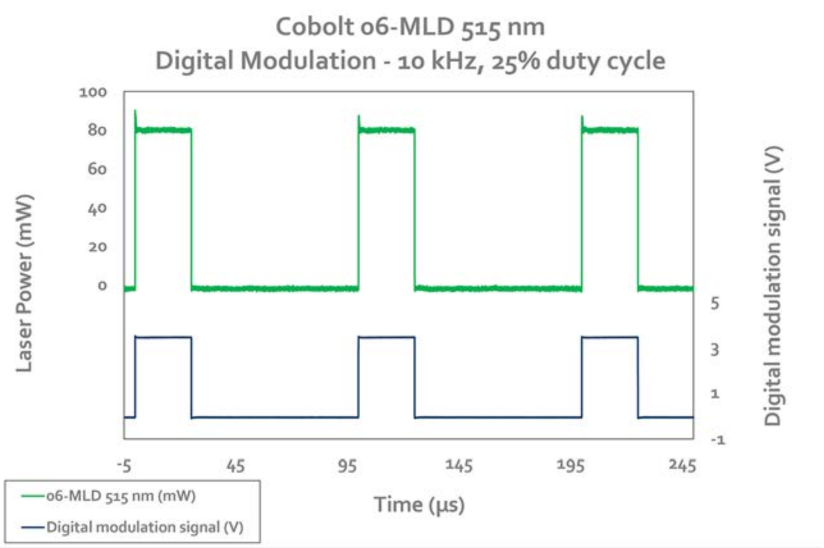


Fig. 4 Output power trace over time of a modulated 515 nm laser diode (Cobolt 06-MLD 515 nm). The modulation characteristics of the 2020 model were optimized for quantum applications. (Source: Hübner Photonics)

Wavelength	510 nm – 560 nm
Modulation rise & fall time	<10 ns
On/off extinction ration	>60 dB
Beam profile	Gaussian
Spectral purity	>40 dB
Polarization extinction ratio	>100:1

Tab. 1 Parameters for the light pulses necessary for the optical initialization and the read-out sequences of the spin state of the NV-centers.

The main advantages of these diode lasers are their modulation capabilities, such as fast analogue and digital modulation with true off state, as well as precise real-time intensity control without the need for an external modulator. They also enable integration of electronics, optics, and a single-mode fiber-coupling into a compact and rugged platform. This allows user-friendly integration with quantum-sensing setups, longer lifetimes without the need for alignment or maintenance, and a more compact footprint. Fig. 4 shows typical modulation characteristics of a 515-nm diode laser with a modulation frequency of 10 kHz.

Outlook

As high-purity diamond quantum sensing cantilevers emerge alongside dedicated control and measurement electronics and high-quality laser sources, the tools for versatile scanning probe quantum sensing experiments are increasingly accessible to a broader audience. Enterprises around the world have also started integrating NV-based ensemble quantum sensors into commercial chip packages, with the goal of realizing the first mass produced products that leverage quantum-enhanced sensing. Further breakthroughs promise to transform quantum-sensing technologies into a versatile range of sensor products.

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[1] *M. Chernobrod* et al.: Spin microscope based on optically detected magnetic resonance, J. Appl. Phys. **97** (2005) 014903.

[2] *P. Maletinsky* et al.: A robust scanning diamond sensor for nanoscale imaging with single nitrogen-vacancy centres, Nature Nanotechnology 7 (2012) 320.

[3] *N. Hedrich* et al.: Parabolic diamond scanning probes for single spin magnetic field imaging, arXiv:2003.01733 (2020)

[4] Photonics Spectra October 2020 New Tools Promise the Next Big Thing for Quantum Sensing | Features | Oct 2020 | Photonics Spectra

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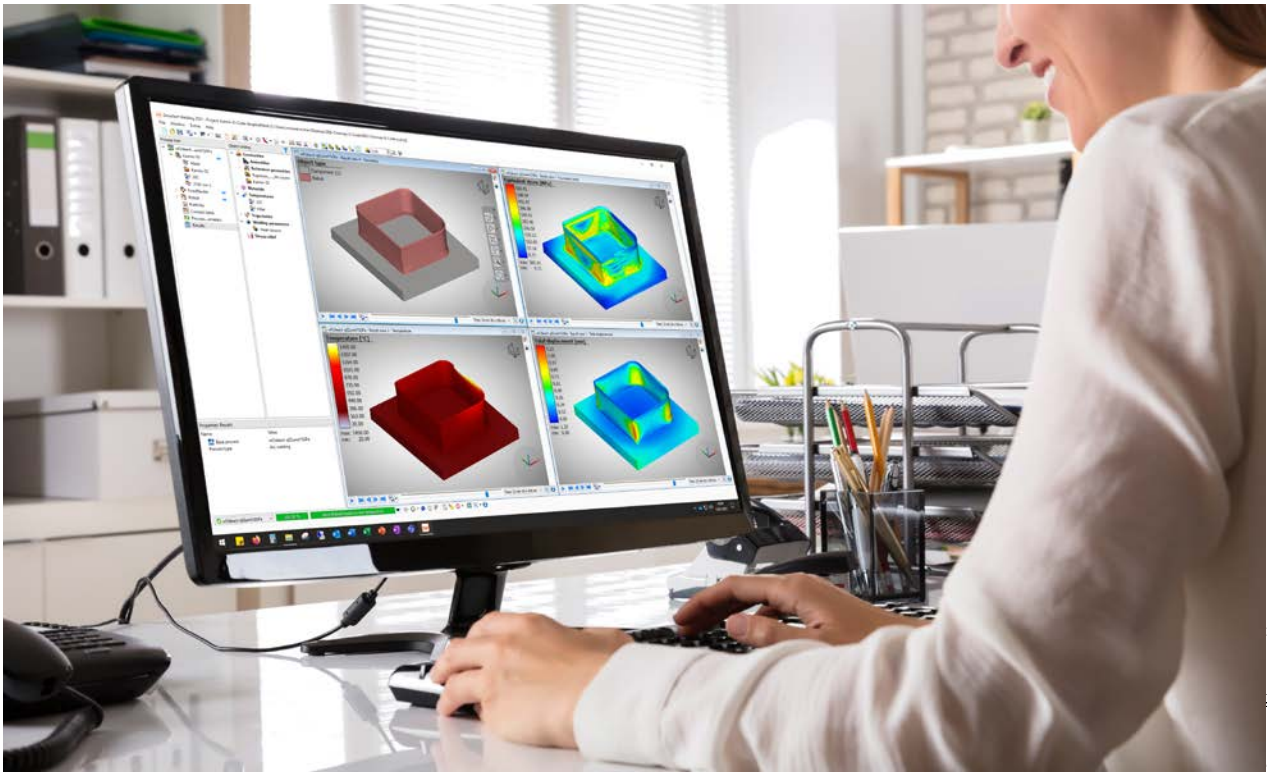
IMProVing directed energy deposition

Industry collaboration overcomes distortion in new DED additive manufacturing processes with simulation

Beatrix Elsner, Frank Silze, and Axel Marquardt



Source all images: Hexagon

▲ Simufact Welding graphical user interface (GUI)

Directed energy deposition (DED) is a powerful additive manufacturing technique that combines a high degree of freedom in design with relatively high deposition rates that can increase throughput. DED structures are created by repeatedly depositing weld beads from powder or wire feedstock, which also makes it an attractive technique for hybrid manufacturing because features can be added to a base component. However, the numerous heating and cooling cycles involved in the deposition process result in a complex thermal history that can entail distort the entire component.

Today, trial-and-error is the common approach to correct for these inadmissible distortions and the cost and time required has reduced momentum in the use of DED. The AGENT-3D project, IMProVe, brought together plasma and laser technology provider Oscar PLT, the chair of material engineering at TU Dresden and manufacturing simulation specialists from Simufact – part of Hexagon's Manufacturing Intelligence division – to demonstrate smarter ways of addressing the distortions that arise during DED processes. IMProVe stands for "Innovative materials, systems and processes by overcoming the process limits in additive manufacturing".

The IMProVe team decided the best approach was to feed the weld robot with a pre-deformed geometry that compensates for the distortions that arise during the DED process, so that it will then adjust the final part to match the intended – and undeformed – shape. The key to this procedure, termed distortion-compensation, is predicting the ideal pre-deformed geometry. As the numerical process simulation specialist, Simufact's remit was to predict the compensated geometry without the need of expensive experimental builds.

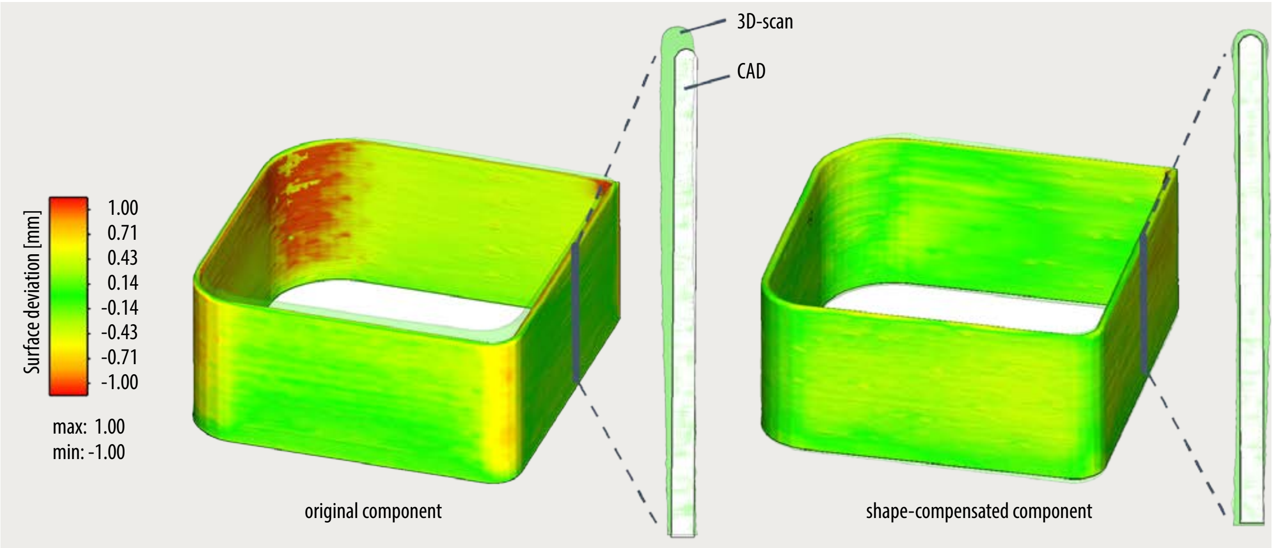


Fig. 1 Shape comparison between CAD (solid color / white) and additive manufactured components (transparent green). The CAD color coding indicates the surface deviation in [mm]. Left: original component. Right: shape-compensated component.

Uncompensated benchmark

The project used sample geometry provided by Oscar PLT. The thin-walled structure consisted of 61 weld tracks, stacked to form a tube with several different corner radii that would be used to probe the effect of sharp turns and smooth curvatures. This was first manufactured without distortion compensation to provide a reference geometry.

To manufacture this part, the start and end points were shifted with each layer to prevent the accumulation of recurring irregularities at these points. A 316 LSi (1.4430) wire feedstock material with a diameter of 1.0 mm was deposited by a coaxial direct-diode laser system at 960 W and a weld velocity of 12 mm/s. The coaxial wire feed ensured high quality deposits in all weld positions.

After the deposition process, the final shape was evaluated using a high-resolution 3D-scan at TU Dresden. Comparison to the CAD data (Fig. 1) revealed a shape deviation of up to 1.4 mm had been introduced during manufacturing that needed to be reduced.

Simulation strategy

While using simulation for shape-compensation is already a state-of-the-art procedure for powder bed fusion processes, the same desirable characteristics that give DED technology additional degrees-of-freedom and high deposition rates also pose new challenges for the setup of numerical process simulations. Unlike powder bed fusion processes, simplified mechanical approaches or techniques based on the effects of cumulative layer heating do not apply. The DED process shares more characteristics with welding, and as such the Simufact Welding simulation environment was used to set up a transient thermo-mechanically coupled model.

To setup the simulation, the 61 weld tracks were directly imported from the robot G-Code (Fig. 2). The track data was also used to create the required deposit geometry in the MSC Apex CAE environment (Fig. 3), where a congruent mesh of hexahedral elements that aligned with the individual weld beads was constructed. The 316 LSi material properties were selected from the Simufact Welding material database and the heat source properties were set according to Oscar PLT's actual DED process parameters. To model the process, an advanced element activation scheme was introduced that can provide both stable deposit element handling and more accurate results. The simulation results were the temperature distribution, stresses and strains, and of course the final distortion of the component.

Print with distortion compensation

Shape comparison between the simulated and real parts revealed that the simulation predicted the part distortion accurately, with only a slight overestimation of the distortion magnitude.

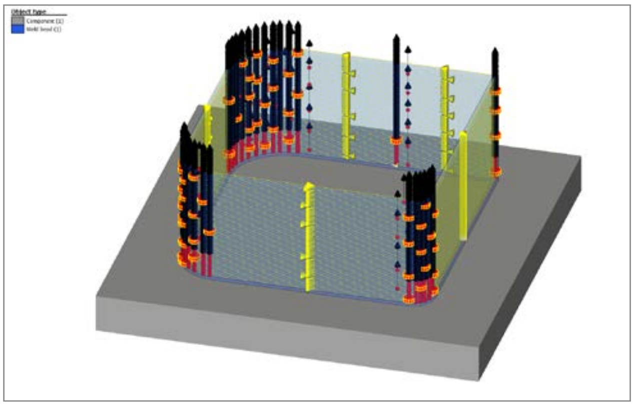


Fig. 2 Model set up in Simufact Welding. Yellow lines indicate the 61 weld tracks with red disks visualizing the weld source at the respective start positions. Black arrows represent the weld orientation. For clarity, the mesh is reduced to transparent blue.

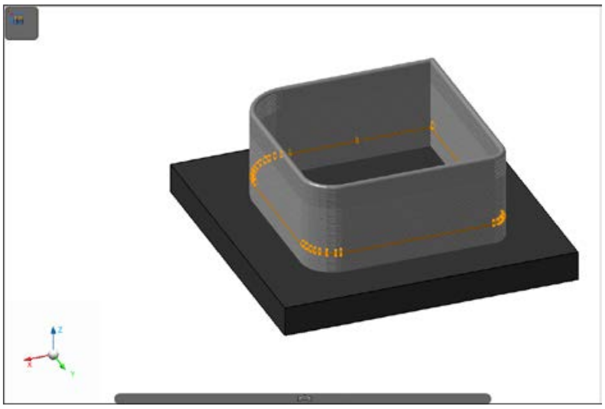


Fig. 3 DED sample geometry positioned on baseplate. The Parasolid was directly generated from the weld tracks defined in the robot G-Code. The volume associated with one of the weld tracks is highlighted (orange).

Both the simulated and real structures bulge inward in the corners of the tube, while the straight edges are less affected. The simulation results were applied to generate the compensated geometry by inverting the calculated distortions. To feed this correction into manufacture, the path planning for the robot was revised for the compensated geometry, and the updated weld paths were utilized to repeat the DED process both virtually and experimentally.

Shape comparison between the 3D-scan of the compensated component and the original CAD data confirms the numerical prediction (Fig. 1): with a maximum shape deviation of less than 0.5 mm, the distortion-compensated additive manufactured part (Fig. 4) is significantly closer to the CAD geometry than the uncompensated test component.

Residual distortions of the component can be attributed to the following two causes. The first lies in the non-linear relation between the distortion and changes to the geometry. Experience with numerical shape compensation of powder bed fusion processes has taught us that this issue can be effectively addressed via iterative compensation schemes. The second reason lies in the finite offset between the initial simulation and the real part. Because the simulation slightly overestimated the distortion, the inversion of the predicted deformation also resulted in over-compensation, as expected. Further calibration of the model would have reduced this effect.

This project aimed to evaluate the benefits arising from a model based on default material data and parameters without the need for experimental input other than the robot G-Code. With more than 60 % of the distortion eliminated, this ambitious target was achieved. Even in cases for which no initial experimental test-build is available, numerical distortion compensation makes it possible to manufacture an optimized part right with the first build.

Having demonstrated successful distortion compensation for a DED process, the project partners Oscar PLT, the chair of mechanical engineering at TU Dresden, and Simufact moved forward industry efforts towards the industrial-scale implementation of DED manufacturing and is looking forward to further collaboration.

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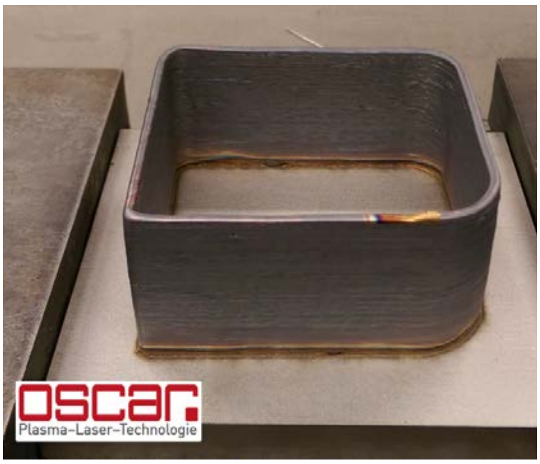

Fig. 4 Final distortion-compensated component

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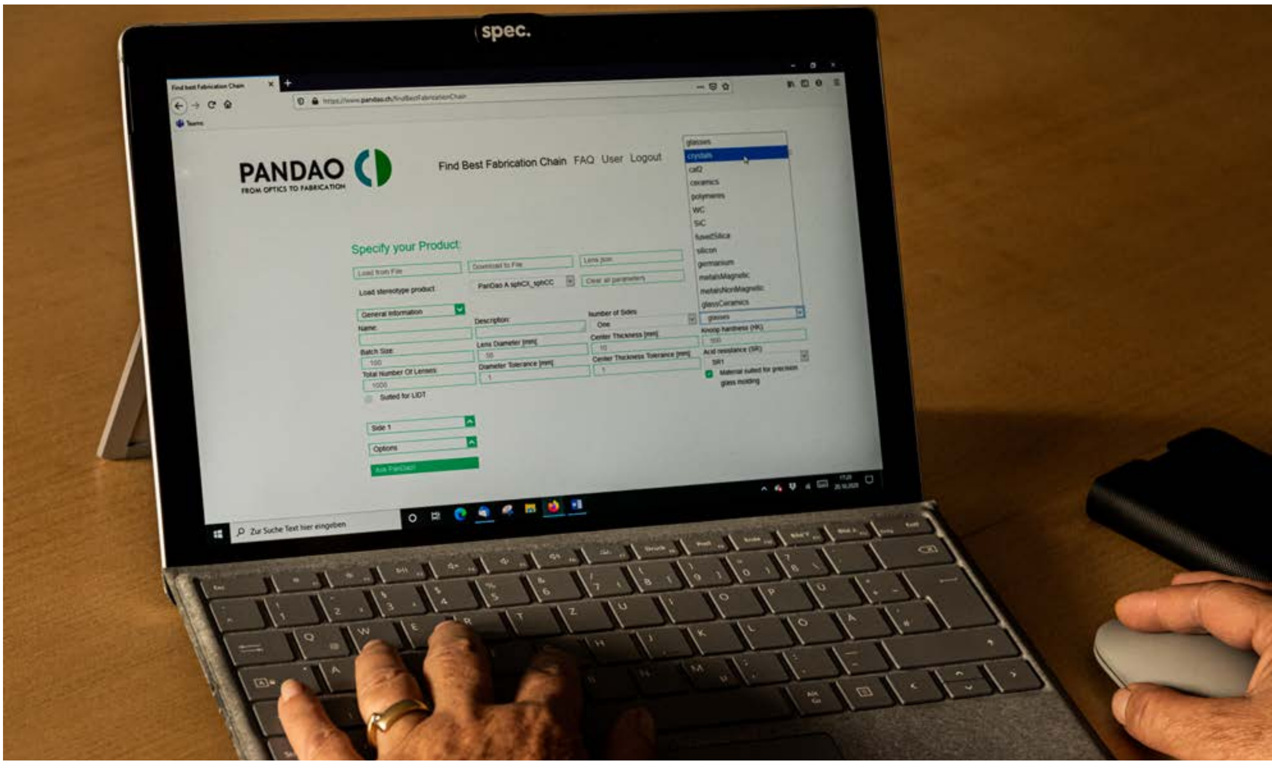
Optical fabrication chain design

By analyzing lens data during optics design, the optimal optical fabrication chain can be determined

Oliver Fähnle, Rolf Rascher, and Marco Tinner



Source all images: PanDao

▲ Fig. 1 Optical fabrication chain design within reach thanks to the online tool.

It takes optical systems such as sophisticated car headlights, telescopes or endoscopes to apply light as a tool, for example to see in the dark, to detect rocks in outer space or stones in a human kidney. As the accuracy of the usage of light tools is increasing rapidly, the quality of optical systems has to follow accordingly. So the process of generating optical systems needs to be optimized to enable the optimum transfer of accuracy and quality to all subsequent entities in the creation process, right from the initial application idea through to final acceptance testing.

Optics systems generation

The generation of optical systems in general is a process with four parties involved (Fig. 2a): starting from (a) the customer, who wants to apply light as a tool and consequently defines application parameters (e.g., MTF, image resolution, dB) followed by (b) the optical system designer, who translates application parameters into optical system layout with optical elements' parameters, described accordingly to ISO10110 standards (e.g., types of glass, shapes and accuracies). Subsequently (c), the optical fabrication chain designer translates the optical system's parameters and tolerances into an optimized fabrication process chain, which is eventually handed over to (d) production, which installs machinery and automation, trains people and manufactures the optical system according to the optical system customer's and designer's requirements (cost, throughput and quality). As in all design and production systems, the majority of the production cost is found in the design phase. Especially in optics manufacturing, the impact of design parameters on production cost is immense because there is a huge variety of manufacturing technologies available, each with its own specific capabilities. Therefore, there is a strong need in industry to already optimize optical designs for producibility and minimum cost during the design stage by modulating optical fabrication chains.

Fabrication chain modulation

While the interface between customer and optical system designer is well supported by optical design software tools,

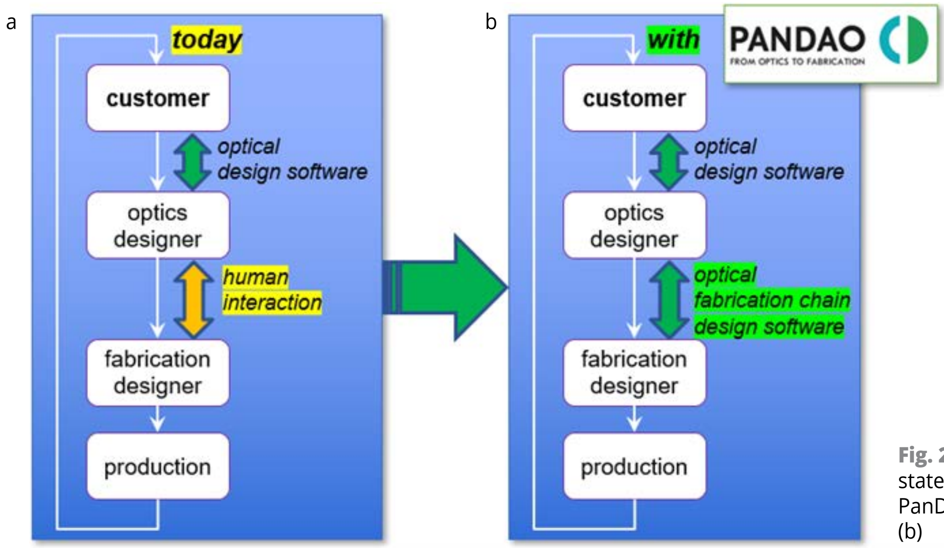


Fig. 2 Generation of optical systems: state-of-the-art (a) and introducing PanDao optical fabrication chain design (b)

the interface between optical system designer and optical fabrication chain designer today is still fully based on human-to-human interactions. This interface is one of the last major roadblocks in the generation of optical systems because it is based on individual judgments, is not deterministic and depends heavily on human experiences and negotiations. Within a Swiss research project called PanDao [1, 2], a new type of software tool has been developed that enables the integration of producibility analyses and fabrication chain optimizations into the optical design process (see Fig. 2b). PanDao reads in lens parameters and tolerances as described in the ISO 10110 standards and generates the optimal fabrication chain at minimum cost, taking more than 360 optical fabrication techniques into account. So, PanDao can be used for cost impact analyses during the design stage as well as for the optimization of supply chain management, for example in identifying optimum suppliers.

Cost impact analysis of an aspherical lens

In the following, PanDao's fabrication cost and technology analysis of a plano-convex-aspherical lens is presented [2], with a 220 mm diameter to be produced in 500 pieces quantity. Shape accuracy on the aspherical side is two fringes irregularity and on the flat side fifth lambda while both sides require 1 nm rms surface roughness level and defect sizes smaller than 0.064 mm (according to ISO10110).

PanDao (Fig. 3) identifies sub-aperture cnc grinding with a final ccp-bonnet polishing to be the optimum fabrication chain to be applied. Total fabrication cost per lens is about 185 euros (taking an average sized central-European company into account: without company's overhead cost and material cost), total order's fabrication cost is 92,500 euros. Two examples are given here that demonstrate how optical design adjustments can impact on fabrication cost.

Changing the lens diameter from 220 mm to 210 mm (modifying the housing design), brings the cost per lens down to 176.80 euros resulting in 4.4 % (or 4,100 euros) fabrication cost reduction overall.

Changing the lens' asphericity (maximum distance from best removal spherical surface to the aspherical surface to be generated) from 4 mm down to 2 mm reduces the fabrication cost per lens down to 155.50 euros per lens, resulting in a 15.9 % (or 14,750 euros) fabrication cost reduction overall (Fig. 4). In this case, it is cheaper to grind and polish the removal spherical surface first (applying full aperture contact) and to use aspheric sub-aperture polishing techniques subsequently, rather than to grind and polish the aspherical surface directly.

	Stage 1:	Stage 2:	Stage 3:
Side 1:	cnc sub aperture rough grinding fabrication price 11.79€	cnc sub aperture grinding fabrication price 29.77€	ccp bonnet fabrication price 99.19€
Side 2:	curve generator rough grinding fabrication price 9.29€	cnc full aperture flats grinding fabrication price 17.62€	cnc full aperture flats polishing fabrication price 17.41€
Total fabrication cost for this lens: 185.08€.			
Investbudget for installing machinery for this fab-chain: 770000€			

Fig. 3 PanDao analysis of the plano-aspherical BK7 lens with €185 fabrication cost per lens (PanDao also determines € 8.70 center grinding cost, € 18.50 coating cost and € 18.20 testing cost).

	Stage 1:	Stage 2:	Stage 3:	Stage 4:
Side 1:	curve generator rough grinding fabrication price 9.29€	curve generator grinding fabrication price 19.89€	cnc full aperture polishing fabrication price 19.89€	ccp bonnet fabrication price 62.10€
Side 2:	curve generator rough grinding fabrication price 9.29€	cnc full aperture flats grinding fabrication price 17.62€	cnc full aperture flats polishing fabrication price 17.41€	
Total fabrication cost for this lens: 155.50€.				
Investbudget for installing machinery for this fab-chain: 560000€				
Bestfit for side 1 is used				
Fabrication chain applying two succeeding steps: a) generation of best starting spherical surface (bsss) and b) asphərizing bsss				

Fig. 4 PanDao analysis of the plano-aspherical BK7 lens (Fig. 1): reducing asphericity from 4 mm down to 2 mm brings a 15.9 % total fabrication cost reduction.

Fabrication chain risk analysis

The optimal fabrication chain meeting the design parameters and tolerances can be established by applying PanDao. Subsequently, the following three novel PanDao parameters are determined which enable a risk assessment of the selected fabrication chain: (a) the 'chain uniqueness', a measure of how many fabrication chains exist within a commercial tolerance band of 20 % above the optimum fabrication chain, (b) the 'chain capability', a measure of the level at which the optical manufacturing technologies must perform their duty in the required manufacturing chain (at 'chain capability' 100 %, the chain has to be applied at state-of-the-art processing level), and (c) the 'chain quickness', information about the throughput speed of the optimal fabrication chain (which is determined by PanDao for minimum cost and risk) with respect to the fastest possible fabrication chain (which is called the express chain and is optimized for speed at reasonable risk while ignoring cost issues).

For the plano-convex aspherical lens analyzed above, the following values result:

- chain uniqueness: eight fabrication chains available within the 20 % commercial band,
- chain capability: chain usage at 99.92 % of state-of-the-art level and
- chain quickness: there is a more expensive, but 6.2 % faster fabrication chain existing.

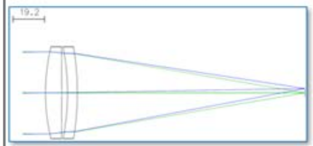
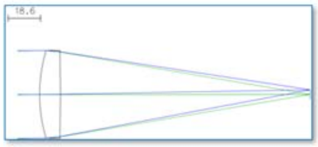
	• focal length = 150, D = 50, NA = 0.1667, field = 5.2mm			
design	spherical doublet N-SF57 		aspherical lens N-BK7 	
performance	full field 1° p-v = 0.991 w rms = 0.1972 w	on-axis 0° p-v = 0.1979 w rms = 0.0380 w	full field 1° p-v = 0.9854 w rms = 0.198 w	on-axis 0° p-v = 0.0012 w rms = 0.0004 w
production cost	18.61 €		32.25 €	
technologies needed	• CNC full aperture polishing (block)		• aspherical side: PGM • spherical side: CNC full aperture polishing (block)	

Fig. 5 Two optical systems, one all spherical and one aspherical, performing at the same optical quality level (1 wave accuracy at the full field position). The PanDao analysis shows that the aspherical objective costs 1.7× more than the spherical one. Taking material cost into account, however, it is half the price.

Judging competing optical design in terms of fabrication cost

A monochromatic collimator has to be designed for a certain optical design task, requiring a wavefront accuracy of 1 wave at the full field of 5.2 mm. As shown in Fig. 5, two competing optical systems have been designed performing at the same quality level: A two spherical lens system and a single aspherical lens system. After conducting a PanDao analysis, the following findings emerge: while the aspherical system is about 1.7 times more expensive in terms of fabrication cost, the spherical system is about 4 times more expensive in terms of material cost. So the overall conclusion is to use the aspherical solution at approximately half the cost of the spherical objective.

Conclusion

In conclusion, a new optical fabrication chain design software tool, called PanDao, has been developed that supports the human-to-human interface between optics design and manufacturing. It enables a cost impact analysis during the design stage and the optimization of optical designs for producibility; consequently, competing designs with comparable performance can be judged in terms of fabrication cost and risk.

DOI: 10.1002/phvs.202100051

[1] *O. Fähnle:* Optical Fabrication Process Modeling, OSA's Optical Design and Fabrication congress, Rode Island, NY, USA , June 2021

[2] *M. Tinner, O. Faehnle*, and *I. Livshits:* PanDao fabrication cost impact analysis software tool for optical designers, EOSAM20 conference on "Optical system design tolerancing an fabrication", European Optical Society (EOS), September 2020

Company

PanDao

You have several possibilities to get in touch with PanDao – a whole new kind of software for the optical industry – and see how it works for you: Use the contact form on our Web site or send an e-mail to info@PanDao.ch
Register for a free and personal online demonstration of the tool or for a free trial. Our team will be happy to introduce you to PanDao.
Also: use our new design-to-fabrication service, where our experts analyze your lens with the PanDao tool and report to you – ask for a quotation.

www.pandao.ch

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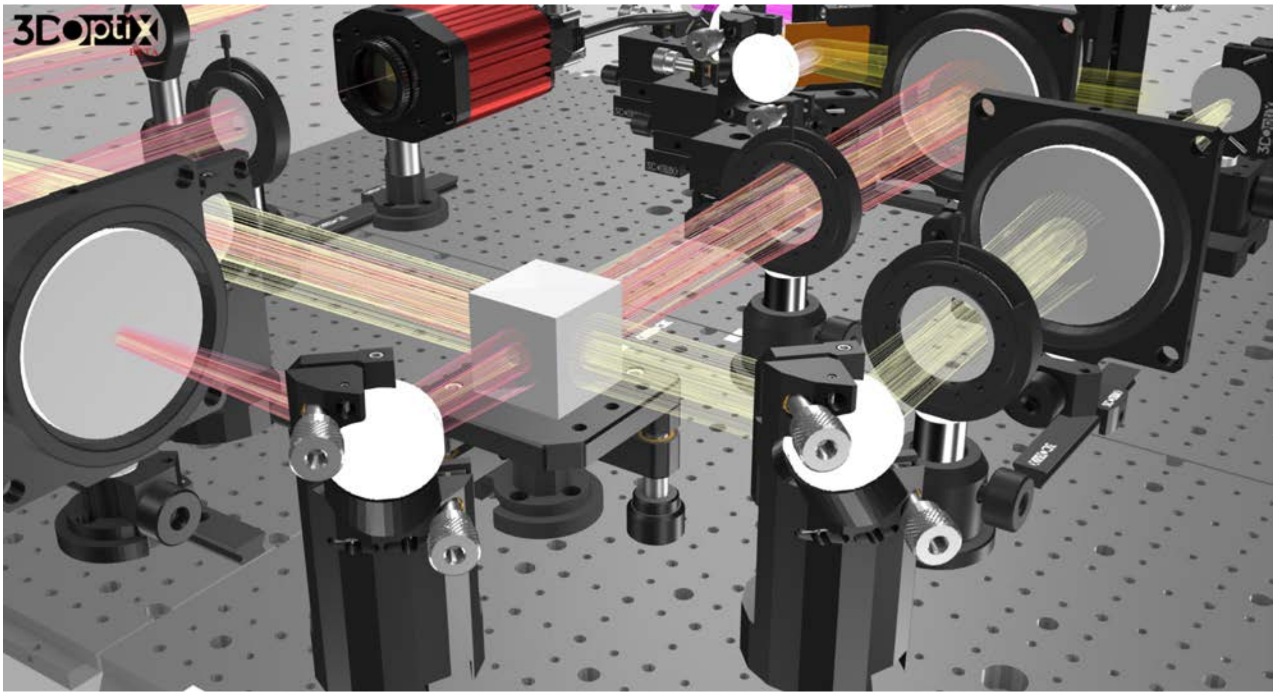
Cloud-based simulation tools for streamlined optical design

3DOptix is a free, easy-to-use, cloud-based optical design and simulation software which includes a suite of discovery tools and drawings

Haim Suchowski



Source all images: 3DOptix

In a stark contrast to traditional optical design and simulation software, 3DOptix offers a free, easy-to-use, cloud-based, collaborative optical design and simulation software. It includes a suite of discovery tools, such as off-the-shelf optical element search, Filter finder tool, professional drawing/media capabilities, educational walk-me, and live mode. The modern UI/UX design allows for a steep learning curve catering to both experienced optical designers and novices.

Optical design software typically provides an optical designer with a set of tools to evaluate and test the performance of an optical system or apparatus. The design process usually begins with basic considerations of the system, preferably based on off-the-shelf components. However, the scouting after per-requirements such components can be sisyphic and often results in creating a manually dedicated optical model of said elements.

Moreover, traditional optical design software requires a for-fee license and runs locally, limiting the ability to share designs and collaborate on designs across teams. Recently, 3DOptix has launched a free, easy-to-use cloud-based optical design and simulation software addressing these main pain points. With an interactive search interface readily including over 60,000 off-the-shelf optical elements from leading vendors and many other simulation functionalities, the efficient optical design is now made accessible and collaborative.

The 3DOptix platform enables the creation of better optical designs with higher efficiency. It includes a ray-tracing engine running in the cloud that calculates the light path through the different optical elements, varying propagation absorption characteristics, and reflecting surfaces. The tool enables the user to quickly plan and test any optical setup with off-the-shelf optomechanics, common light sources and a huge variety of optical elements from the different catalogs or customized optics by the end-user. Thanks to its cloud architecture, akin to other cloud-based tools such as Google Docs, the platform allows easy sharing of models and collaboration between users. Finally, The simulation software generates a blueprint of your setup for fast implementation. In this article, we wish to introduce the readers to some of the unique functionalities of the 3DOptix' platform that are appealing to experienced optical designers and novices alike.

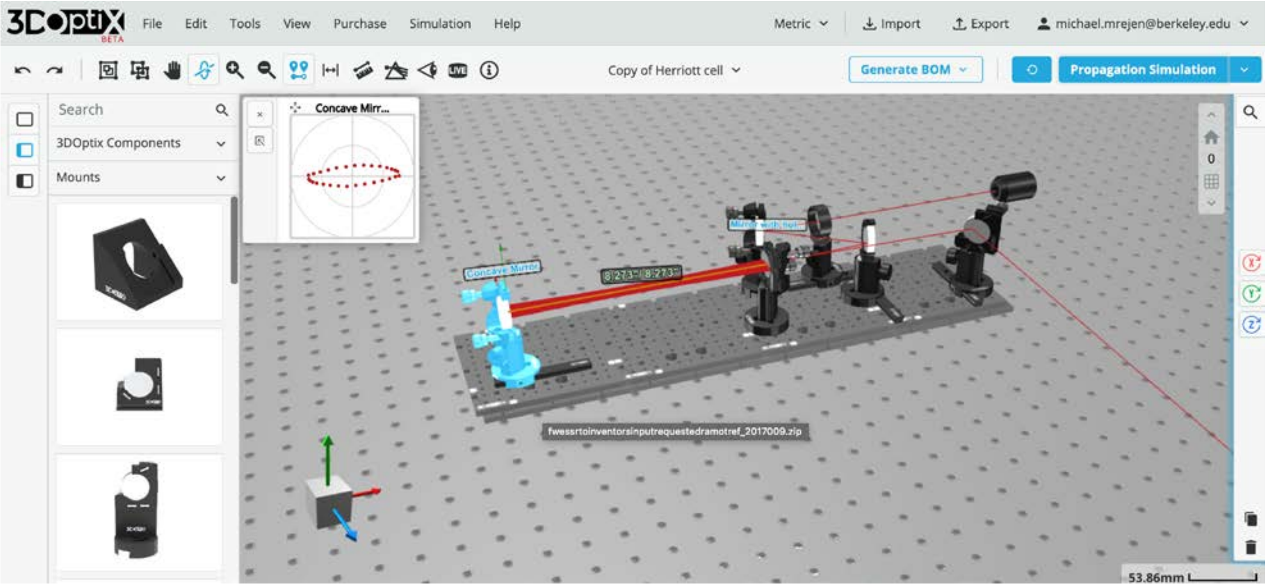


Fig. 1 3DOptix' web-based interface: a multipass Herriott cell has been designed and simulated.

Main interface and ray optics engine

The main interface (Fig. 1) offers a modern, highly intuitive and functional user experience, where the user defines real-life optomechanics, the sources (including wavelengths, beam shape, divergence, polarization etc.) and the detectors (including spectrometers). A vast selection of optics is available and is covered in the next section. Once the layout is setup the ray propagation is run on the cloud with the 3DOptix ray tracing engine based on sequential and non-sequential ray tracing.

In sequential ray tracing, the optical elements are intersected one at a time, and light travels from surface to surface in a predefined order. It is used to model the geometrical components of optical systems, define the optical properties of objects, approximate light sources with directional rays and then predict real-world system behavior by observing the propagation of these rays through system models. In contrast, non-sequential ray tracing allows for random and multiple encounters between rays and surfaces by process of automatic ray splitting. Because non-sequential ray tracing allows rays to scatter and interact with system components as they do naturally, this method enables the user to predict the real-world behavior of optical systems more accurately than in sequential ray-tracing.

The 3DOptix optics finder and filter match

3DOptix offers a powerful search interface where over 60,000 mirrors, lenses, beamsplitters, prisms, gratings and more from twenty (!) leading suppliers can be searched based on their optical and geometrical properties. When incorporating these elements in the layout, the raytracing engine automatically takes into account all the optical and geometrical properties (index of refraction, focal length, coatings, dimensions, dispersion and more) as provided by the included vendors.

3DOptix has also released an innovative CAD import wizard, serving all CAD file formats. The CAD wizard provides the option to add multiple reflective surface locations, allowing the combination of CAD design and Optical simulation in a single platform.

One task that can be particularly frustrating for optical designers is finding spectral filters based on specific specifications such as different transmission (reflection) windows, size, substrate material. To solve this known hassle, 3DOptix now incorporates an advanced filter match search engine (Fig. 3).

In the Filter Finder interface, the user selects the type of filter desired optical property (transmission, reflection), The required spectral operation (shortpass, longpass, bandpass, notch), the relevant

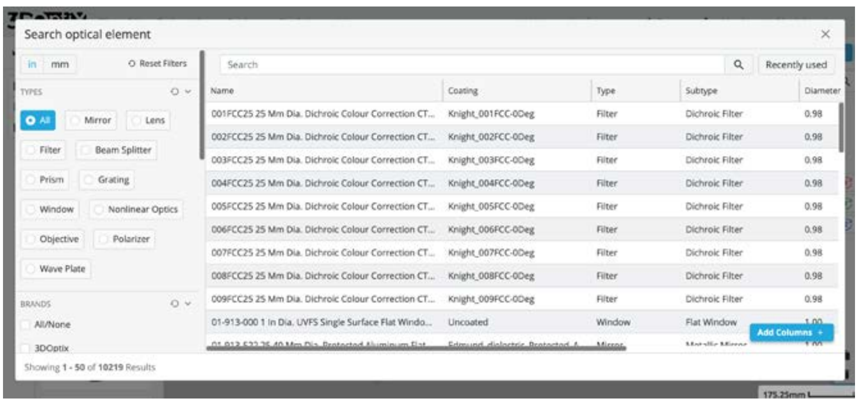


Fig. 2 3DOptix optical element finder

Company

3DOptix

3DOptix started the online optical design and simulation platform to get more done in a frictionless remote environment. Our easy reliable and innovative optical cloud platform provides optical CAD Design, simulations, and widgets services. 3DOptix helps optical designers create better designs with higher efficiency and a clear path to implementation.
Founded in 2017, 3DOptix is a spin-off company from the Femto-Nano Laboratory at Tel Aviv University and is headquartered in Tel Aviv, Israel.

www.3doptix.com

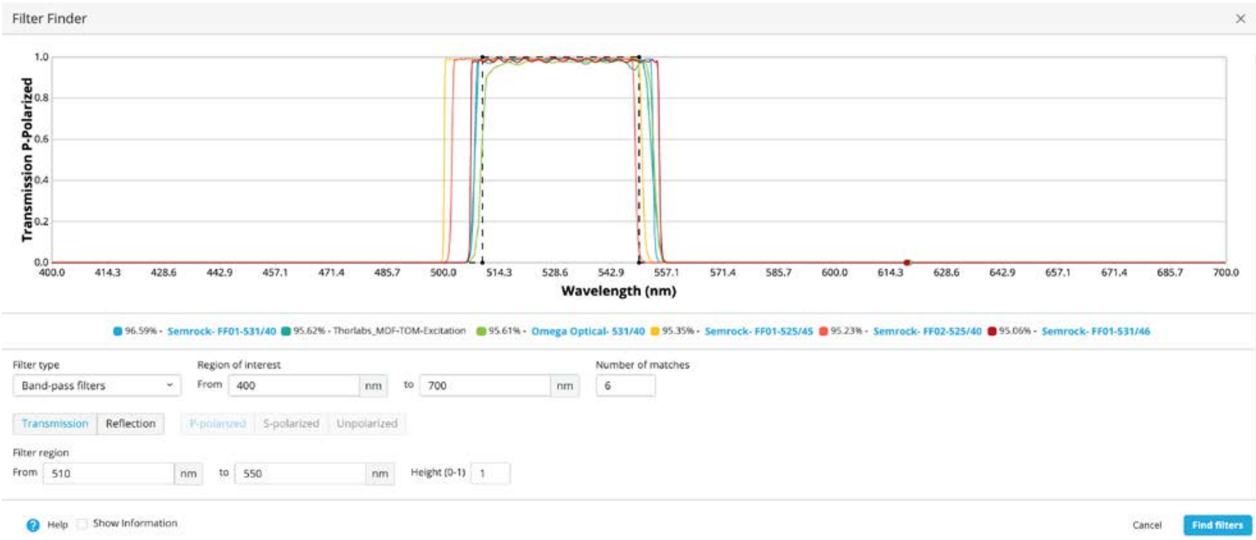


Fig. 3 3DOptix Filter Finder in action

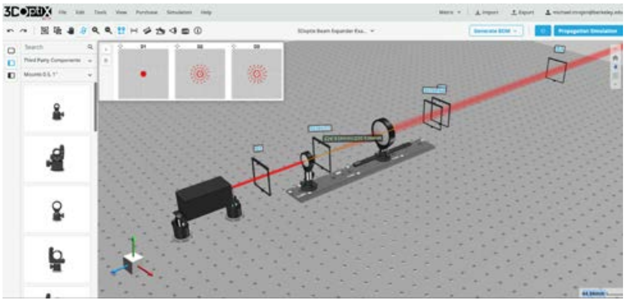


Fig. 4 Automatic optimized placement of lenses in a beam expander

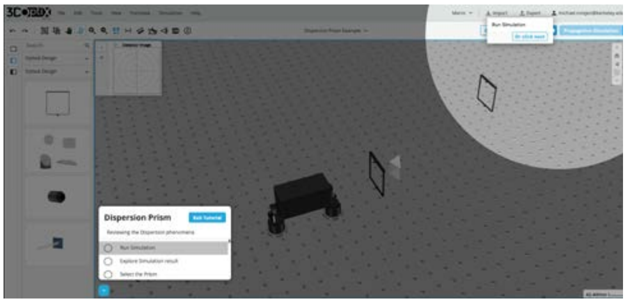


Fig. 5 Walk-me tutorials for easy learning of the 3DOptix functionalities

wavelengths (cut-on, cut-off etc.) and the number of desired matches.

Once those are selected, the 3DOptix Filter Finder draws from its vast database which includes over 10,000 filters and coatings and returns the highest matches from off-the-shelf components and plot them with the requested profile for comparison. A degree of correlation matching is also provided to guide the designer's decision. Finally, a direct link to the vendors' websites for relevant components is provided for easy ordering.

Automatic optimized placement of optical elements

Another feature of interest in the 3DOptix platform is the automatic optimized placement of optical elements (Fig. 4). One major task when it comes to optical system design is finding the optimal position of the optical elements according to some design target i.e. reduced aberration, optimal spot size, etc. The 3DOptix interface now includes an automatic optimized optical elements placement. For now, beam expanders can be optimized with respect to collimation and more advanced systems are being released.

Walk-me tutorials

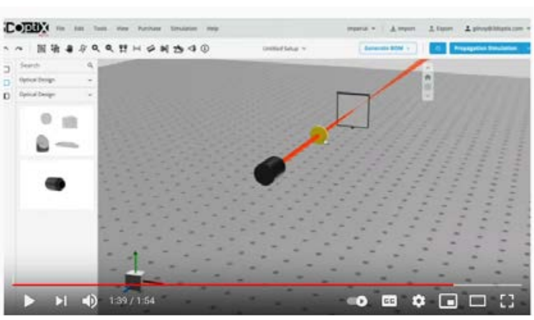
The 3DOptix user experience has been designed with the state-of-the-art UI/UX methodologies. To further ease the learning curve of new users, detailed and clear Walk-me tutorials are included, for free as well. Under the Help section, users can find tutorials that will walk them through the main functionalities of the 3DOptix platform to bring them up to speed in a limited time.

Conclusion

Traditional optical design software requires an a-priori knowledge or an extensive search of per-requirements optical elements. Moreover, their ability to allow collaboration among designers is limited. To address these limitations in this article, we have introduced some of the recent features added to 3DOptix, the free, cloud-based, user-friendly optical design simulation software.

For more information and access to our services, please visit www.3doptix.com

DOI: 10.1002/phvs.202100054



Video at www.youtube.com/watch?v=7w201wBY_0I

Author

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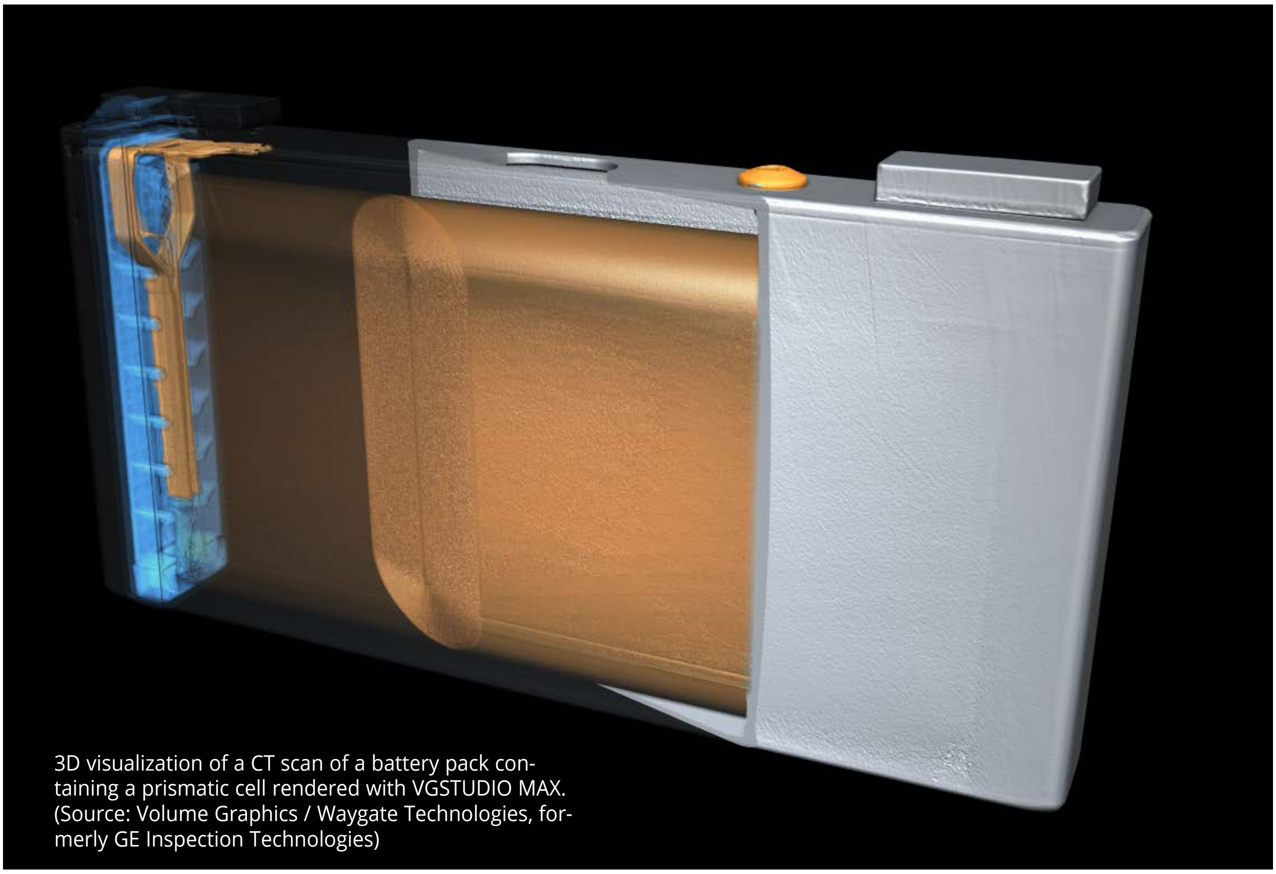
Intelligent quality assurance for batteries

Computed tomography detects defects in modern lithium-ion batteries



3D visualization of a CT scan of a battery pack containing a prismatic cell rendered with VGSTUDIO MAX. (Source: Volume Graphics / Waygate Technologies, formerly GE Inspection Technologies)

Because of their high-power density, rechargeable lithium-ion batteries are subject to strict quality monitoring. Industrial computed tomography is increasingly being used to detect any defects before delivery or during production.

The CT analysis software from Volume Graphics provides functions that allow a deep look into the inner workings of energy storage devices. Methods from the field of artificial intelligence are also becoming increasingly important.

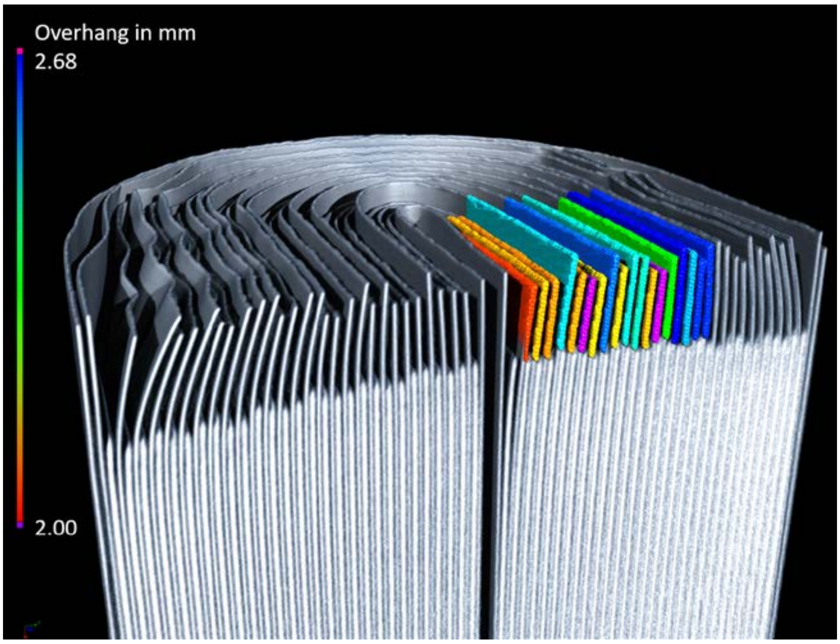
Not only because of the debate on climate change, lithium-ion batteries are attracting increased attention for a number of reasons these days. They are seen as key components for the mobility of the future. Compared with other types of storage, Li-ion batteries have convincing advantages: no memory effect, lower self-discharge, and even more crucial, significantly higher power density. A $LiCoO_2$ cell delivers 3.6 V of voltage – three times that of a metal hydride cell and almost twice that of a lead-acid cell.

But there are two sides to every coin. Wherever lithium or its compounds are involved, safety becomes an issue. Lithium is a highly flammable alkali metal. In addition, strong currents sometimes flow in the cells, especially if the charging process is too fast. It is not uncommon for extreme temperature developments to occur with subsequent deformations. In the worst case, there is a risk of fire or explosion. This is why we read about recalls time and again.

Although computed tomography cannot reveal the electrochemistry within the cell, it can illuminate the 'mechanical' inner workings. A thermal runaway can have mechanical causes. Conversely, electrochemical processes can change mechanical conditions. The insights that CT can contribute are increasingly being used by research institutions and battery manufacturers. "The testing of batteries opens up a whole new field of application for CT," explains Pascal Pinter, product manager material research and development at Volume Graphics. "With our software, both geometric measurements and material testing are feasible."

Production-accompanying application

The experts at Volume Graphics do not just have finished cells in mind. "Due to the very complex process of manufac-



Volume Graphics' software allows the measurement of anode overlap. The amounts of protrusion are shown using a color scale, which in this example ranges from 2 mm (red) to 2.68 mm (blue; source: Volume Graphics / Waygate Technologies)

turing these batteries, CT-based analyses already make sense during production, for example to remove defective components from the process chain at an early stage," continues Pinter. With a high-resolution CT scanner, for example, irregularities in the layers of the electrode packages become visible. Delaminations are a typical phenomenon. You can also localize foreign particles, for example residues resulting from the cutting process. Other contaminants can be welding particles that form when the contacts are attached, or the housing is sealed. The major risk that these types of foreign particles pose is short circuits.

An important internal dimension to be monitored during manufacturing is the so-called anode overlap. The anode is always dimensioned so that it overlaps the cathode. This is to counteract lithium plating and possible damage to the cell. Lithium plating means that pure Li is deposited in the anode. It is then no longer available for the formation of ions. A constant anode protrusion requires high precision in manufacturing. It is defined by the manufacturer and can be checked using the CT analysis software from Heidelberg.

Finally, you can use CT for inspection and forensics in the after-sales phase, for example to determine the cause of a device failure. It can also be used in the context of comprehensive sustainability concepts. Cells that no longer meet the original requirements of e-mobility due to capacity loss may still be usable for stationary applications. A look at the inner workings could therefore help to save valuable resources.

Artificial intelligence detects defects

When examining batteries using CT, quality engineers face a challenge: The interesting structures in the gray-scale images provided by the CT scanner often have very low contrasts. This is due to the low-density differences of some materials. In addition, the films and coatings of the cell packages are very thin and close together. It is sometimes very difficult to determine which irregularities can be interpreted as defects, scattered radiation, or artifacts. The central question is: which voxel (the smallest 3D element in the CT model, similar to pixels in 2D images) is a defect voxel, and which is not? Even experienced quality engineers often come to different interpretations. The only thing left for them to do is to adjust or vary the scan parameters of their system accordingly and, if necessary, to pay special attention to certain regions of interest (ROI).

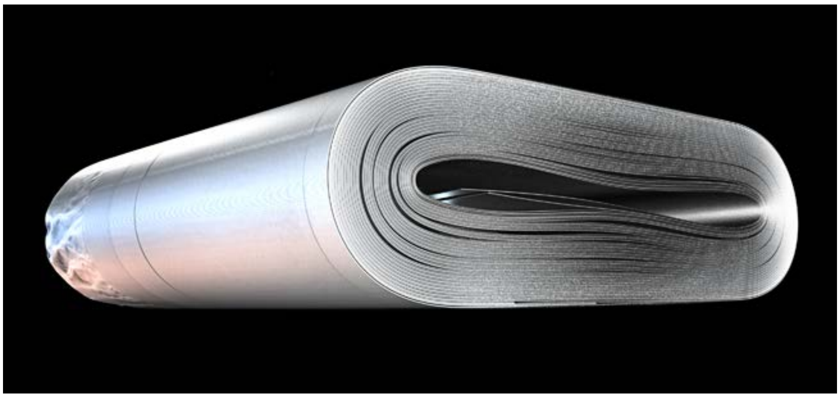
This is the conventional approach – but it has its drawbacks. On the one hand, it depends on the operator and is therefore individual; on the other hand, it requires additional time, which has to be added to the scanning time. Since the sometimes-filigreed structures of the cell interior require high-resolu-

Company

Volume Graphics

The company in Heidelberg, Germany, has been developing software for non-destructive testing based on industrial computed tomography (CT) for over 20 years. Customers around the world, e.g., from the automotive, aerospace, and electronics industries, use Volume Graphics software for quality assurance in product development and production. Since 2020, Volume Graphics has been part of Hexagon, a global leader in sensor, software, and autonomous solutions.

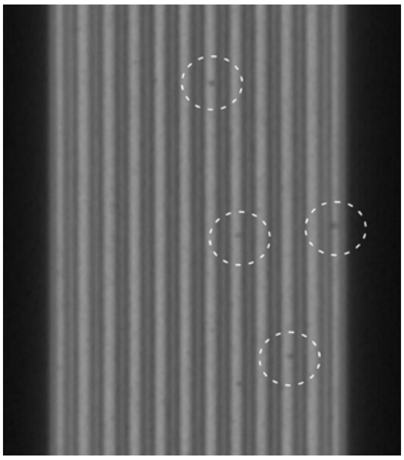
www.volumegraphics.com



Delaminations, the detachment of the electrode windings or coatings, can be easily visualized with CT. (Source: Volume Graphics / Waygate Technologies) tion scanners, and therefore long scanning times, things quickly become tight, especially when accompanying random sample inspections must be carried out within a specified cycle time.

In such cases, the deep learning method proves to be particularly effective. This approach works well, for example, when examining cast-metal workpieces, where similar tasks have to be performed as in the case of battery cells. Deep learning comes from the field of artificial intelligence and is based on artificial neural networks (ANN), which are modeled on the human brain. What neurons or nerve cells are to biology, interconnected mathematical functions that calculate a certain output depending on the input are to the digital world. The application of such a network in CT-based defect detection delivers very accurate results and does so in a very short time. The network needs something like a memory for this, i.e., it has to be 'trained' with defect data.

But where does this data come from? There are basically two ways to generate it: Firstly, the simulation of artificial defect data based on the model of real defects. Special software is available for this purpose. The physical effects that occur during scanning can be imitated in this way. The result is an artificial but accurate pool of data. Secondly, the defect data can also be taken from real components. In this case the defects have to be detected manually. This approach requires a larger number of real objects. Which method is most suitable must be decided on a case-by-case basis. "If customers commission us to train an ANN, we will provide them with an algorithm that fits their problem exactly," emphasizes Pinter. "If necessary, they should provide us with a certain number of battery cells, both intact and containing critical faults."



The contrasts of CT images of the internals of batteries are very low, making it difficult to interpret any defects. Artificial intelligence methods such as deep learning provide clarity. (Source: Volume Graphics)

When the trained ANN is applied, the irregularities in the real scans are compared with the defect data 'in memory'. The ANN then identifies similarities. It reliably answers the question of what a defect voxel is and what is not. An advantage for series-part inspection: The method is also very accurate at lower resolutions, as they occur in the case of shorter scan times and could also allow inline inspection of battery cells in the long term.

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https://www.volumegraphics.com/en/products/vgsm.html

Info

Key technology of the hour: lithium-ion batteries

The quality characteristics that play a role in Li-ion batteries only become fully clear when the structure and manufacturing processes are known: First, we have to distinguish between three cell designs: 1. cylindrical cells (e. g. in notebooks, hand tools), 2. prismatic cells (e. g. in vehicles), 3. flat pouch cells (e. g. in smartphones). A cell mainly consists of two electrodes: an anode and a cathode. If you look at the discharge process, the anode is the negative pole, the cathode the positive pole. In addition, there is an ion-permeable separator foil between the two electrodes and an ion-conductive electrolyte.

The electrodes, in turn, consist of so-called active materials. Graphite is generally used for the anode, and lithium cobalt dioxide ($LiCoO_2$) for the cathode. Other lithium compounds with manganese, nickel, iron, or aluminum oxide are also suitable and may lead to different voltages. Both active materials are deposited as slurry on both sides of a metal carrier foil, also called current collector. Copper is used for the anode and aluminum for the cathode. During charging, Li-ions flow from the cathode to the anode to embed themselves in the graphite layer; during discharging, the flow direction is reversed.

The thicknesses of the current collector foils are 10 – 25 µm, those of the electrode coatings 200 – 250 µm. In order to be able to contact the electrodes later, the carrier foils remain uncoated in the edge area. After coating, the films go into the dryer and then into a calendering unit, which compresses and smooths the active coatings under 150 – 250 bar. A laser or knife then cuts the films into sheets. Sheets are cut out for pouch cells. In the meantime, cleaning takes place; both cut quality and cleanliness are important quality criteria.

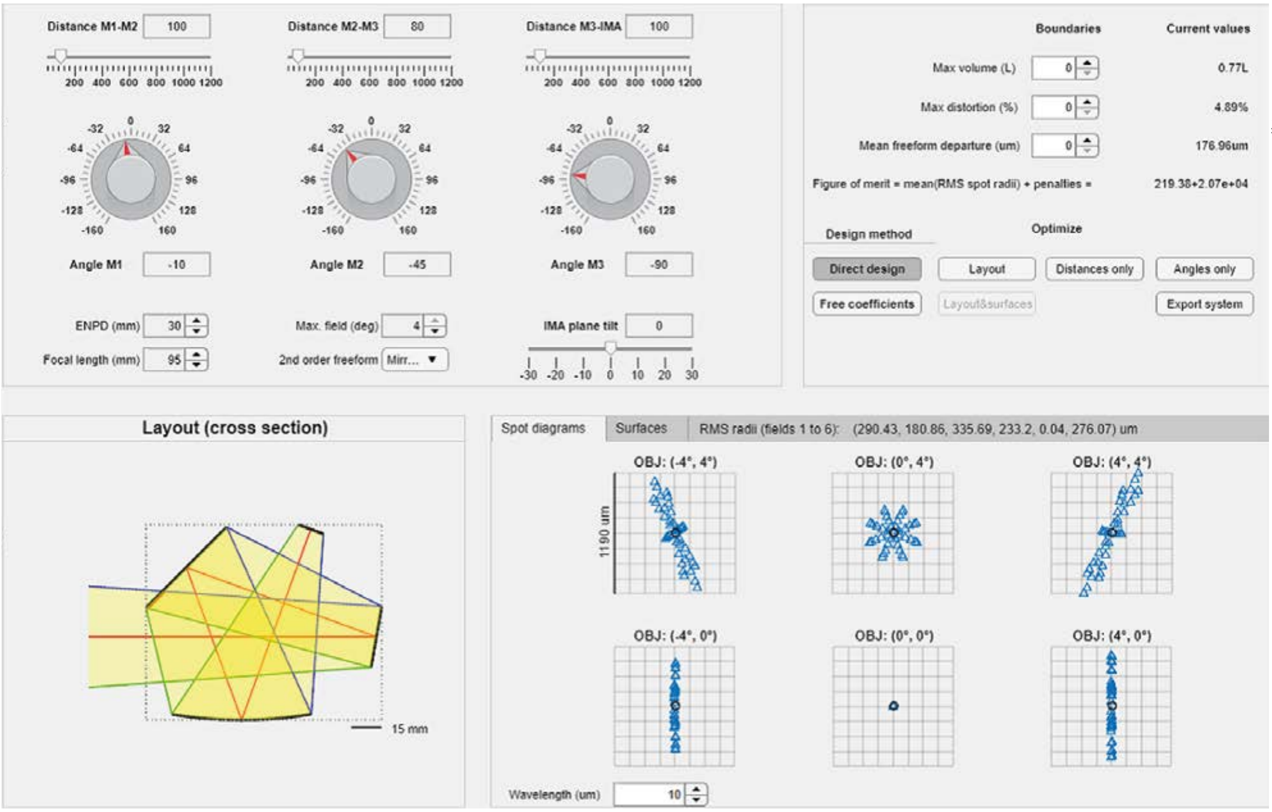
Finally, the blanks are wound or stacked together with the separator film to form a jellyroll and pressed.

This results in the following structure for the wraps/stacks: anode-separator-cathode-separator-anode-separator-cathode, etc. Connectors are welded to the uncoated aluminum and copper foil overhangs, also known as current collectors, by means of laser or ultrasound. Prepared in this way, the packages are usually placed in an aluminum housing, which is welded except for a filling hole for the electrolyte. Once the electrolyte has been introduced, the first charging process, also known as formation, takes place. The final mechanical process is the closing of the housing by a rivet or a weld. A subsequent 'aging' period of several weeks serves to verify the function.

'First time right' freeform optics

A systematic and highly effective tool to design imaging systems from scratch

Fabian Duerr and Hugo Thienpont



Source all images: B-PHOT

▲ Included freeform design web app. A how-to-use manual is provided in the Supplementary Information document of article [1].

Today's design of optical systems relies largely on efficient ray tracing and optimization algorithms. Such a 'step-and-repeat' approach to optical design typically requires considerable experience, intuition, and trial-and-error guesswork. Brussels Photonics (B-PHOT) researchers have developed a design method that allows highly systematic generation and evaluation of directly calculated freeform design solutions and enables a rigorous, extensive, and real-time evaluation in solution space. Readers have the opportunity for hands-on freeform design experience via an open-access web application.

For more than 150 years, scientists have advanced aberration theory to describe, analyze and eliminate imperfections that disturb the imaging quality of optical components and systems. Simultaneously, they have developed optical design methods for and manufacturing techniques of imaging systems with ever-increasing complexity and performance up to the point where they are now including optical elements that are unrestricted in their surface shape. These so-called optical freeform elements offer degrees of freedom that can greatly extend the functionalities and further boost the specifications of state-of-the-art imaging systems. However, the drastically increased number of surface coefficients of these freeform surfaces poses severe challenges for the optical design process, such that the deployment of freeform optics has remained limited until now. Today, the design of optical systems largely relies on efficient raytracing and optimization algorithms, for which a variety of commercial software and optimization algorithms are available. During an optical design cycle, different parameters of the optical system such as the optical material parameters, radii, coefficients and positions of the optical surfaces are varied to optimize a defined merit function that indicates the image quality for a given field of view. These merit functions are typically 'wild' with many local minima, and there is no guarantee that local or global optimization algorithms will lead to a satisfactory design solution. A successful and widely-used, optimization-based optical design strategy therefore consists of choosing a well-

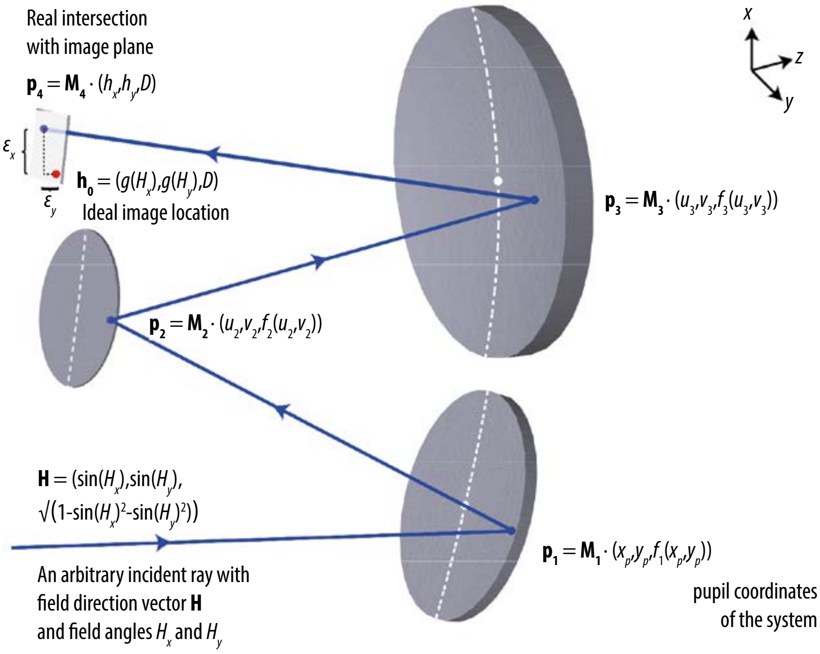


Fig. 1 Schematic layout of a typical plane-symmetric freeform optical system, here consisting of three mirrors. The plane of symmetry is indicated by the white dotted lines on each surface. The ray path of an arbitrary ray is shown including the introduced mathematical description of the initial ray direction and intersections with each mirror and the local transverse ray aberrations ε_x and ε_y in the image plane.

known optical system as a starting point (e.g. from literature) and steadily achieving incremental improvements. Such a 'step-and-repeat' approach to optical design, however, requires considerable experience, intuition, and guesswork, which is why it is sometimes referred to as "art and science". This applies especially to freeform optical systems.

In this article, we briefly review the recently presented 'first time right' optical design method for freeform imaging systems. The patented method [1] is based on solving differential equations derived from Fermat's principle of least time by using a power series approach. The method enables the calculation of the optical surface coefficients that ensure minimal image blurring for each individual order of aberrations. As such, it offers a disruptive methodology to design optical imaging systems from scratch to facilitate a fast-track uptake of freeform elements in the next generation of high-end imaging systems. A more detailed mathematical description can be found in a recently published article [2].

Mathematical formulation

There are various possibilities to classify aberrations in freeform optical systems according to the overall system symmetry present: (1) systems with two orthogonal planes of symmetry, (2) systems with one plane of symmetry, and (3) systems without any symmetry. Here, we will only consider systems with one plane of symmetry as it is the most common category. The two other symmetry categories can be treated similarly. Following an approach similar to that used in most aberration theories, we assume an arbitrary ray that is emitted from an object at infinity with a field direction vector $\mathbf{H}$ for field angles H_x and H_y that passes through the pupil of the system (here, first surface in Fig. 1) at $(x_p, y_p, f_1(x_p, y_p))$, and that finally intersects the image plane at $\mathbf{h} = (h_x, h_y, D)$. This intersection can be written in vector form as a series expansion $\mathbf{h} = \mathbf{h_0} + \boldsymbol{\varepsilon}^{(1)} + \boldsymbol{\varepsilon}^{(2)} + \boldsymbol{\varepsilon}^{(3)} + \ldots$ where $\mathbf{h_0} = (g(H_x), g(H_y), D)$ denotes the ideal (aberration-free) image location as a function of H_x and H_y. The deviation from the ideal image location is then described by the ray aberration polynomials $\boldsymbol{\varepsilon}^{(i)} = (\varepsilon_x, \varepsilon_y, 0)$ as the sum over the transverse ray aberration series $\varepsilon_x (x_p, y_p, H_x, H_y)$ and $\varepsilon_y (x_p, y_p, H_x, H_y)$ in x- and y-direction, respectively.

We now consider a sequence of N refractive and/or reflective optical surfaces f_i $(i = 1 \ldots N)$ (in Fig. 1 these are three mirrors) aligned along a principal ray path. To describe their surface functions, we use a power series representation

$$f_i(x, y) = \sum_{s=0}^{S_i} \sum_{t=0}^{T_i} \frac{1}{s!t!} f_{i,st}\, x^s y^t$$

with coefficients $f_{i,st}$. Next we introduce the ray mapping functions $(u_i(x_p, y_p, H_x, H_y), v_i(x_p, y_p, H_x, H_y))$ in x and y direction that describe where an arbitrary ray, described by variables (x_p, y_p, H_x, H_y), will intersect each optical surface f_i. We can define the respective orientation (tilts) of all elements, namely the object, the individual surfaces, and the image plane, through rotation matrices $\mathbf{M_H}$, $\mathbf{M_i}$ and $\mathbf{M_h}$, applied to $\mathbf{H}$, $\mathbf{p_i} = (u_i, v_i, f_i)$ and $\mathbf{h}$, respectively. The ray path from the object to the image plane then consists of $(N+1)$ segments $d_1 \ldots d_{N+1}$ that describe the intermediate optical path length distances for an arbitrary ray. Vector geometry enables us to express these distances weighted by the refractive indices $n_{i,i+1}$ of the surrounding materials. By applying Fermat's principle, we can derive two sets of differential equations for all defined distances d_i pairwise from object to image space

$$D_{i,x} = \partial_{u_i} (d_i + d_{i+1}) = 0 \ (i = 1 \ldots N) \quad (1)$$

$$D_{i,y} = \partial_{v_i} (d_i + d_{i+1}) = 0 \ (i = 1 \ldots N) \quad (2)$$

Institute

Brussels Photonics (B-PHOT)

Brussels Photonics (B-PHOT) is a self-supporting research and innovation institute of the Faculty of Engineering of the Vrije Universiteit Brussel with 35 years of experience in photonics education, research and innovation. With an international and gender-balanced community hosting 70 experts from 20 countries, our continuous mission is to advance photonics, the key digital technology that uses the unique properties of light to innovate. B-PHOT is also uniquely involved as coordinator of the EC-funded pan-European initiatives "ACTPHAST" and "PhotonHub Europe" that support both SMEs and researchers with photonics innovation.

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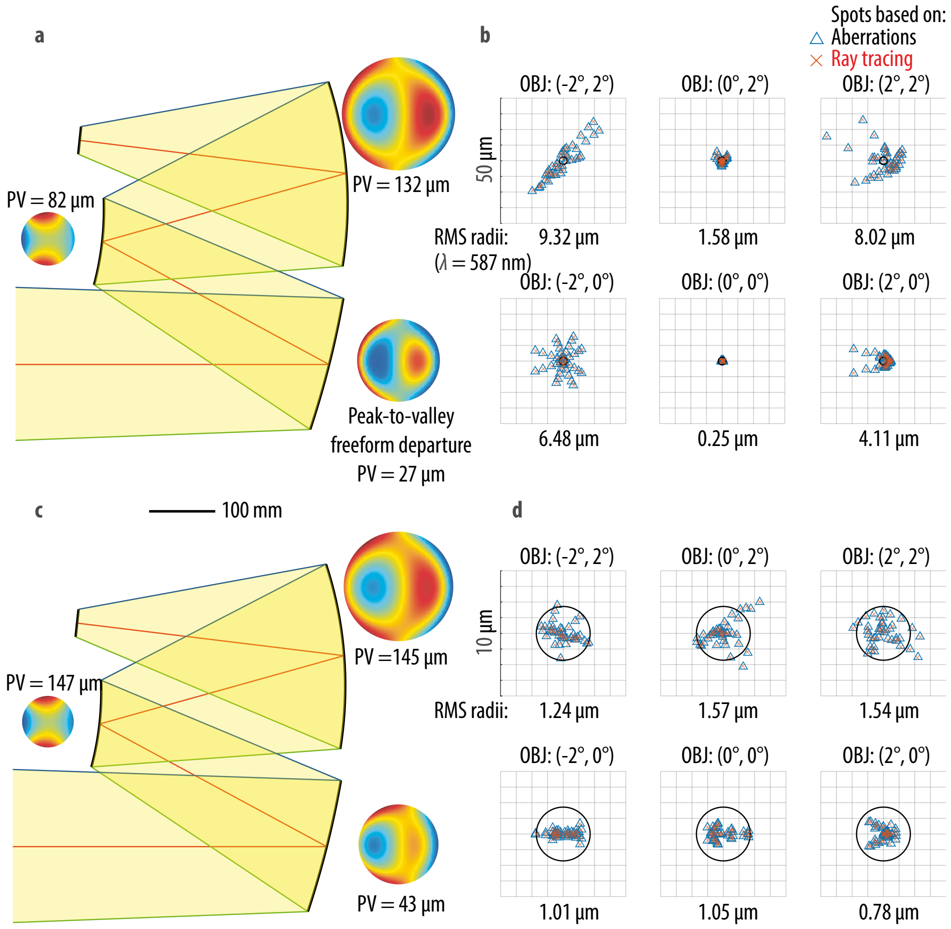

Fig. 2 The 'First time right' design results for the three-mirror imager: cross-section of the directly calculated initial system combined with peak-to-valley freeform departures (PV) from the base sphere for the primary, secondary and tertiary mirror (a), corresponding spot diagrams for six selected fields based on aberration calculations (blue triangles) and ray tracing (red crosses) in comparison (b), cross-section of the subsequently optimized system combined with peak-to-valley freeform departures (PV) from the base sphere for each mirror (c), corresponding spot diagrams for the same six fields based on aberration calculations (blue triangles) and ray tracing (red crosses) in comparison (d).

An optical system consisting of N surfaces is thus fully described by N differential equations $D_{i,x}$ and N differential equations $D_{i,y}$ for $i = 1 \ldots N$, for a given but arbitrary pupil plane.

Suppose that all functions h_x, h_y, u_i, v_i and f_i are analytic and smooth solutions of the differential equations $D_{i,x}$ and $D_{i,y}$, then Taylor's theorem implies that the functions must be infinitely differentiable and have power series representations. We can employ a power series method to find solutions to the derived differential equations $D_{i,x}$ and $D_{i,y}$. This method substitutes the power series expressions into the differential equations to determine the values of the series coefficients. To calculate certain coefficients, we differentiate Eqs. (1) and (2) with respect to x_p, y_p, H_x, H_y evaluated at

$$\lim_{x_p\to 0}\lim_{y_p\to 0}\lim_{H_x\to 0}\lim_{H_y\to 0}\frac{\partial^j}{\partial x_p^j}\frac{\partial^k}{\partial y_p^k}\frac{\partial^l}{\partial H_x^l}\frac{\partial^m}{\partial H_y^m}D_{i,x} = 0\ (i = 1 \ldots N) \qquad (3)$$

$$\lim_{x_p\to 0}\lim_{y_p\to 0}\lim_{H_x\to 0}\lim_{H_y\to 0}\frac{\partial^j}{\partial x_p^j}\frac{\partial^k}{\partial y_p^k}\frac{\partial^l}{\partial H_x^l}\frac{\partial^m}{\partial H_y^m}D_{i,y} = 0\ (i = 1 \ldots N) \qquad (4)$$

Once the entrance pupil diameter, focal length, field of view and design wavelength are specified, we can establish these differential equations and initiate the method as follows: (1.) solve the non-linear first order case ($j + k + l + m = 1$) using a standard non-linear solver; (2.) solve the linear systems of equations in ascending order ($j + k + l + m = 2, 3, \ldots$) by setting unwanted aberrations to zero or by minimizing a combination thereof as required by the targeted specifications of the imaging freeform system. It is important to emphasize that these two solution steps are almost identical for all freeform optical designs. We calculated the surface coefficients up to the sixth order, and the mapping and aberration coefficients up to the eighth order throughout this article.

Three-mirror example

The first reference design example is a catoptric imaging system by Bauer et al. for the visible spectrum with x-z plane symmetry and the object at infinity [3]. It consists of three freeform mirrors with the stop at the first mirror. The targeted system volume is sixty liters. So the layout of the optical components can be described by three distances (between mirror 1 and 2, mirror 2 and 3, and mirror 3 and the image) and four rotation angles (one for each of the three mirrors, and one for the image), which provides seven geometrical degrees of freedom for the optical designer. These distances and angles can now be (manually) adjusted to create an unobscured starting geometry that meets certain geometrical constraints such as the given target system volume. The calculated design that we obtained by optimizing the seven degrees of freedom of the geometry is shown in Fig. 2a, where the system layout cross-section is combined with the full 3D peak-to-valley freeform departures (PV) from the best-fit base sphere for each mirror, respectively.

Fig. 2b shows the spot diagrams for six selected fields based on our aberration calculations up to the 8th order. With an average RMS spot radius of about five micrometers, our directly calculated system provides an already well-corrected 'first time right' solution that can be readily further optimized. Next, all forty previously calculated surface coefficients and the initial seven degrees of freedom are used as variables for further optimization, e.g. using Matlab's lsqnonlin solver. After ten iterations, which only take a few minutes, the system already reaches diffraction-limited performance for almost the full field of view. The optimized design shows slightly increased and moderate freeform departures distributed among the three mirrors. The results are shown in Fig. 2c and 2d accordingly. The aberration-based performance estimation of our method was found to be in excellent agreement with spot diagram data from classical ray tracing (calculated using Zemax, overlaid red cross symbols in Fig. 2b and 2d). We have developed a web-based application for the three-mirror design case that allows users to experience this unique design method hands-on and in real time. The graphical user interface and the usage of the app are explained in depth in the Supplementary Information document of our recently published article [2].

Catadioptric design example

As a second example from literature, we have selected a monolithic freeform objective for a very compact infrared camera with four optical surfaces [4]. We chose this example to illustrate the scalability of our design method, well beyond the capabilities of most present-day direct freeform design approaches. We furthermore highlight its holistic character, since in this case we are dealing with a catadioptric system with freeform and aspherical surfaces. Here we design an objective consisting of three aspheres and one freeform at the second surface, with the stop placed at the first surface. We follow this reference as closely as possible with the following system requirements: an $f/1.4$ design covering a 37 × 25-degree field-of-view, an 8.4 mm entrance aperture, made of optical-grade germanium and operating in the long-wave infrared region (LWIR) from 8 to 12 µm. With the object at infinity, the layout of the system can be described by four distances and five angles, defining the principal ray path from object to image and the respective positions and orientation of all surfaces and corresponding rotation matrices. Optimizing the nine initial degrees of freedom of the geometry yields an already well-corrected and unobscured system. Fig. 3a shows the configuration of the system of comparable size to the cited reference design. The peak-to-valley freeform departure (PV) from the best-fit base sphere for the second freeform surface is added next to it. Fig. 3b shows the corresponding spot diagrams for six selected fields (we used fifteen fields for the optimization) based on our aberration calculations. With an average RMS spot radius of about 51 µm, we achieved an excellent starting point for further optimization. All surface coefficients are now set as variables for further optimization using, for example, Matlab's lsqnonlin solver. The results are shown in Fig. 3c and 3d.

Within a few minutes, the system reaches a close to diffraction-limited performance in the LWIR band for the full field of view with an acceptable distortion of less than five percent. Chromatic aberrations are very well controlled due to the relatively low dispersion of Germanium in the LWIR band. In addition, the relatively small angles within the monolith due to the high refractive index lead to better aberration control in general. This spot diagram-based performance is in excellent agreement with spot diagram data from classical ray tracing.

This example clearly demonstrates again the highly effective nature of our proposed design and evaluation method. In addition, it highlights two further important features: (1.) our method allows the simple combination of refractive and/or reflective surfaces of spherical, aspheric or freeform shapes; (2.) the method also straightforwardly enables the number of calculated surfaces of an optical system to be increased without considerably increasing the computational complexity of the problem. This direct path to scaling the number of calculated surfaces is a result of the fact that the intermediate optical path length distance expressions do not depend on the number of considered surfaces.

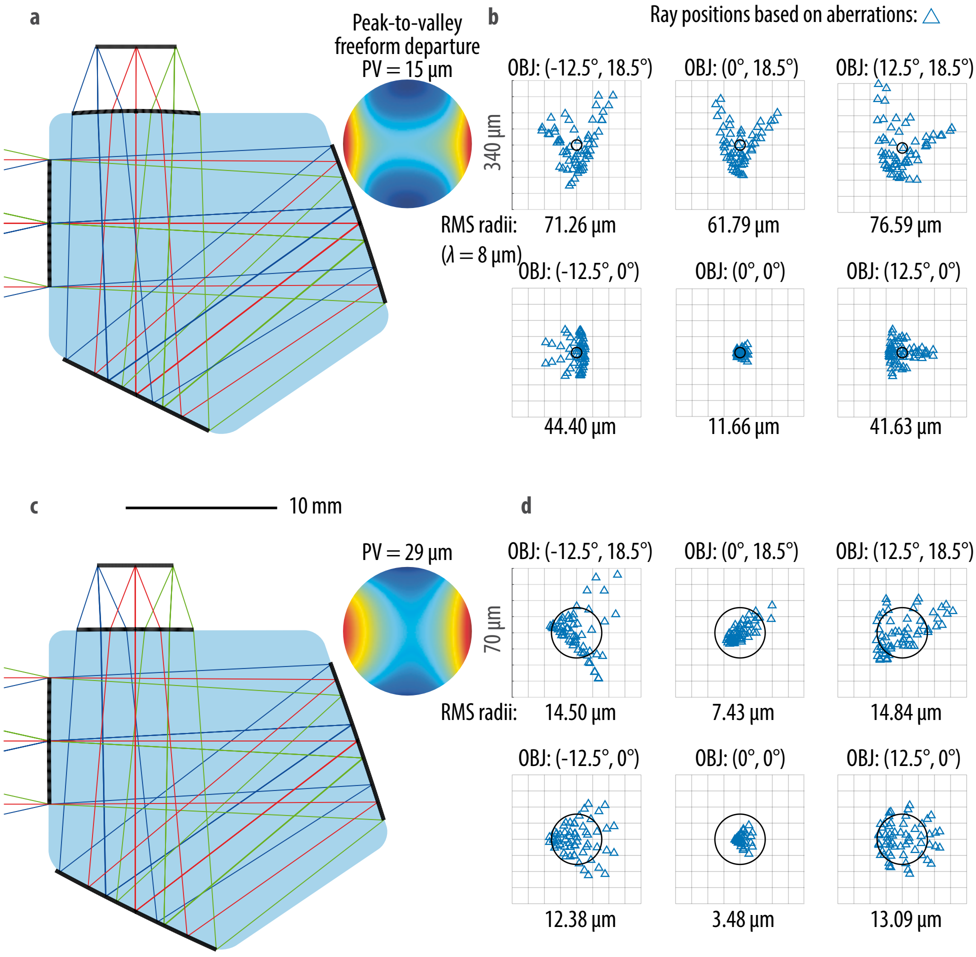

Fig. 3 The 'First time right' design results for the four-surface monolithic infrared camera objective: cross-section of the system from direct calculations with peak-to-valley freeform departure (PV) from the base sphere for the second and only freeform surface (a), corresponding spot diagrams for six selected fields based on aberration calculations (b), cross-section of the subsequently optimized system combined with peak-to-valley freeform departure (PV) from the base sphere for the second surface (c), corresponding spot diagrams for the same six fields based on aberration calculations (d).

Three-mirror, four-reflection designs

Despite faster f-numbers and larger FOVs, freeform four-mirror designs bring in extra complexity to both mirror fabrication and system assembly compared to three-mirror designs. As a promising alternative, we have investigated a revived type of multireflection mirror system where at least one of the mirrors is passed twice in the ray path with a desired overlap (not mutually centered to provide more flexible designs) [5]. This contrasts the well-known Offner designs where two individual mirrors share separate parts (no overlap) of a joint substrate without a desired overlap in their footprints [6].

With regard to the four-reflection cases, there are three possibilities to generate the 'double-pass surface', respectively mirrors M1/3, M1/4 and M2/4.

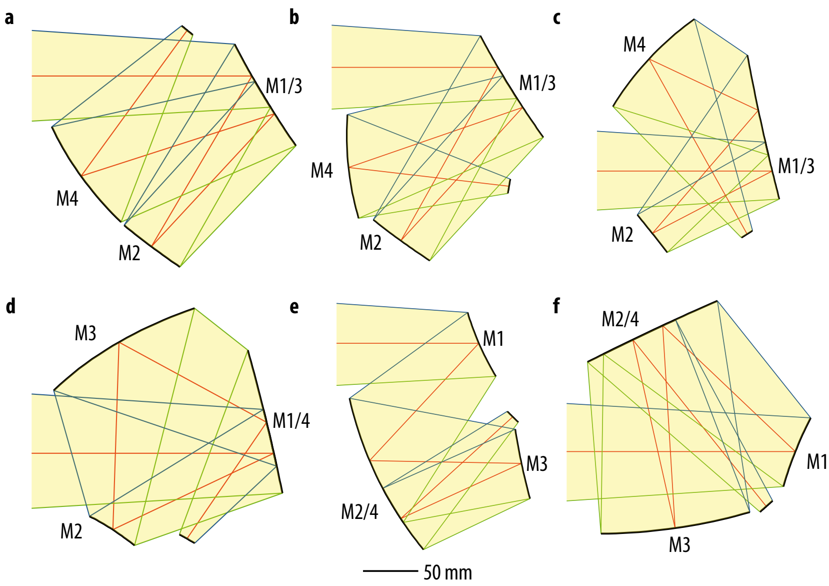

Fig. 4 The proposed freeform optical design method unlocks a new class of three-mirror, four-reflection freeform systems with three different 'double-pass surface' options. (a – c) M1/M3, (d) M1/M4, (e – f) M2/M4. Note all the layouts are based on real ray-tracing with the design parameters for visualization: focal length 250 mm, *f*/2.5, FOV 7.2° × 7.2°.

Several showcases of each type have been calculated by the proposed 'first time right' method, summarized in Fig. 4.

In summary, the three-mirror, four-reflection concept presented here can yield high-performance yet compact designs, opening up a greatly extended design space to explore and seek new competitive freeform systems [7].

Conclusions

Equipping lens and/or mirror-based optical systems with freeform optical surfaces makes it possible to deliver highly original imaging functionality with superior performance compared to their more traditional (a)spherical counterparts, such as an enhanced field-of-view, increased light-collection efficiencies, a larger spectral band and greater compactness. Until now, mathematical models and design strategies for freeform optics remained limited and failed to provide deterministic solutions. In particular, the identification of a suitable initial design has often proven to be a painstaking and time-consuming trial-and-error process.

In this article, we reviewed the first deterministic direct design method for freeform optical systems that is not restricted by the aberration terms that can be controlled. The method relies on Fermat's principle and allows the highly systematic generation and evaluation of directly calculated freeform design solutions that can be readily used as a starting point for further and final optimization. As such, this new method enables the straightforward generation of 'first time right' initial designs that provide a rigorous, extensive, and real-time evaluation in solution space when combined with the available local or global optimization algorithms.

*

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[1] Optical design methods for imaging systems and optical systems designed therewith, Patent No. WO/2019/129872 (2019).
[2] *F. Duerr, H. Thienpont:* Freeform imaging systems: Fermat's principle unlocks 'first time right' design, Light: Science & Applications **10** (2021) 95.
[3] *A. Bauer, E.M. Schiesser,* and *J. P. Rolland*: Starting geometry creation and design method for freeform optics, Nature Communications **9** (2018) 1756.
[4] *S. Kiontke:* Monolithic freeform element, Proceedings of SPIE 9575, Optical Manufacturing and Testing XI, 95750G (2015)
[5] *D. R. Shafer:* Anastigmatic two-mirror telescopes: some new types, Appl. Opt. **16** (1977) 1178.
[6] *S. H. Kim, H. J. Kong, J. U. Lee, J. H. Lee,* and *J. H. Lee*: Design and construction of an Offner spectrometer based on geometrical analysis of ring fields, Rev. Sci. Instrum. **85** (2014) 083108.
[7] *Y. Nie, D. R. Shafer, H. Ottevaere, H. Thienpont,* and *F. Duerr*: Automated freeform imaging system design with generalized ray tracing and simultaneous multi-surface analytic calculation, Optics Express **29** (2021) 17227.

http://first-time-right.b-phot.org/webapps/home/session.html?app=FTR

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Controlling 100 lasers automatically via the cloud

Using open-source cloud technology to manage laser manufacturing software

Source: Fraunhofer ILT

In the Cluster of Excellence "Internet of Production" (IoP), two hundred scientists at RWTH Aachen University in cooperation with Fraunhofer ILT have set up a data center for controlling and monitoring industrial processes. The concept for this is based on a project for controlling laser systems developed at the Fraunhofer Institute for Laser Technology ILT and uses the open source software Kubernetes. A corresponding system has been running successfully at the institute for two years, and with it the institute can automatically and remotely install the software for new lasers in just a few minutes.

The task: setting up complex laser systems efficiently

An ultrashort pulse (USP) laser is a complex system that can ablate almost any material with micrometer precision. Numerous sensors control the machine and guide the laser process. The software that controls the components and reads the data from the sensors is accordingly diverse. In industrial production, many such systems are often used in parallel, and it is not uncommon to have fifty of them side by side. But how can their software be installed efficiently? And how can they be controlled centrally?

The solution: starting from scratch

Moritz Kröger, a research associate at the chair for laser technology LLT at RWTH Aachen University, an associated chair at Fraunhofer ILT, was faced with precisely this issue: "With the current programmable logic controllers, you can control one device quite well, but hardly a dozen or even one hundred at the same time." In this context – of controlling fifty to one hundred lasers – conventional concepts would foreseeably not be sufficient for installing new software for these systems and evaluating sensor data in real time.

▲ The Kubernetes software is used, for example, to control ultrashort-pulse laser systems. The scientists are currently researching the automatic evaluation of measurement data.

The solution? "We completely reprogrammed the machine control system," reports Kröger. "This allowed us to rely on proven open source software right from the start, which gives us more compatibility and development options for distributed systems." This way, the institute is able to control and optimize laser processing operations that must

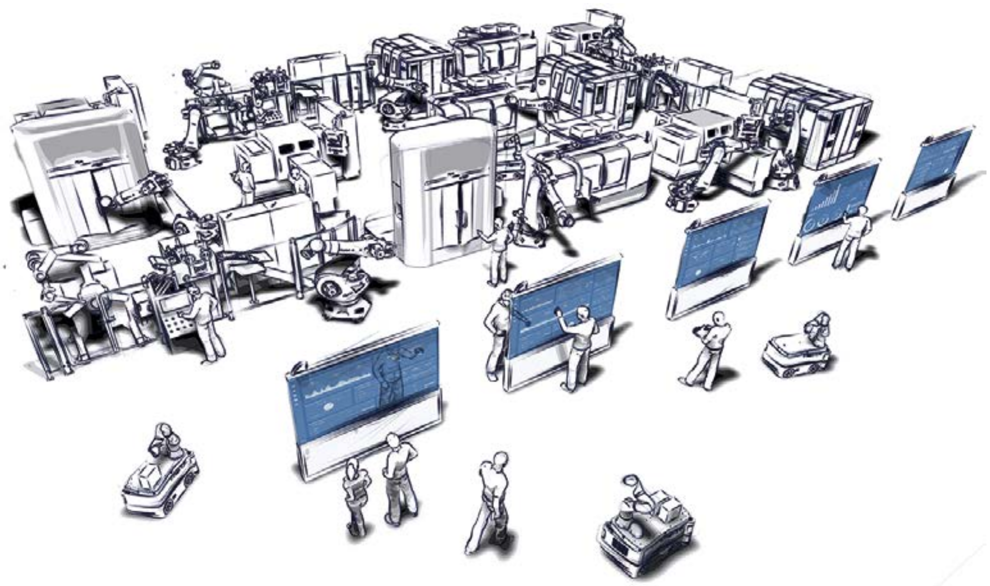

Fig. 2 In the “Internet of Production” cluster of excellence, scientists are working on cloud-based control systems for the production of the future, among other things. (Source: M. Riedel / Internet of Production)

take into account, for example, data from the scanner controls, sensor data from different sources and analysis data during the ongoing process. The project started in 2018, and the control system is now running stably in the beta phase at Fraunhofer ILT.

At the core of the data center is Kubernetes, open source software that can automatically install, scale and maintain application programs on distributed computing systems. Kubernetes was originally designed by Google and is supported by leading cloud platforms including Microsoft Azure, IBM Cloud, Red Hat OpenShift, Amazon EKS, Google Kubernetes Engine and Oracle OCI.

Distributed computing for the automated manufacturing of the future

The potential has been recognized at RWTH Aachen University. As early as 2019, the concept was adopted by the Fraunhofer ILT for a data center at the university. In the cluster of excellence “Internet of Production”, engineers are working on the digitalization of manufacturing technology. Their goals are to increase and simplify cross-domain collaboration as well as to securely bundle all relevant data from many different sources in real time, and all in the context of cyber-physical systems and the fourth industrial revolution.

More than 35 university and non-university research institutions as well as the three Fraunhofer Institutes – FIT, ILT and IPT – are involved. More than

Infobox

Software Tools for Laser Material Processing

Software is an elementary part for the control and automatization of processes and the handling of digital data. Often very specific adaption is necessary to fulfil the various requirements according to a process. Therefore, the Fraunhofer Institute for Laser Technology ILT is developing software tools highly optimized for laser material processing. This includes the generation of NC programs, control of optical systems and data processing.

Fig. LMDCAM-CAM software for laser metal deposition (Source: Fh. ILT)

CAM for laser materials processing

Computer-assisted manufacturing (CAM) plays an important role in the process chain for laser material processing. Based on a digital model of the component NC programs for the control of the mechanical axes and the optical systems are generated.

For laser metal deposition (LMD) processes Fraunhofer ILT developed the software “LMDCAM“. This software is a powerful tool path planning instrument for repairing and additive manufacturing of components. It is optimized for working with large data files (e. g. triangulated data acquired by a measuring device). The user is able to interact with all entities (like CAD data and the tool path) and thereby complex and individual tasks can be solved. After generating tool paths the resulting machine movement can be checked for collisions or exceeded axis velocities. For this task the software includes a build-in machine simulation tool. Using the included programmable post processor tool paths can be exported as NC programs which can also support multiaxes systems (e.g. robots).

For laser micro structuring galvanometric laser scanners for laser beam deflection and short-pulse laser sources are used. Compared to LMD laser micro structuring is a subtractive manufacturing process where the material is ablat-

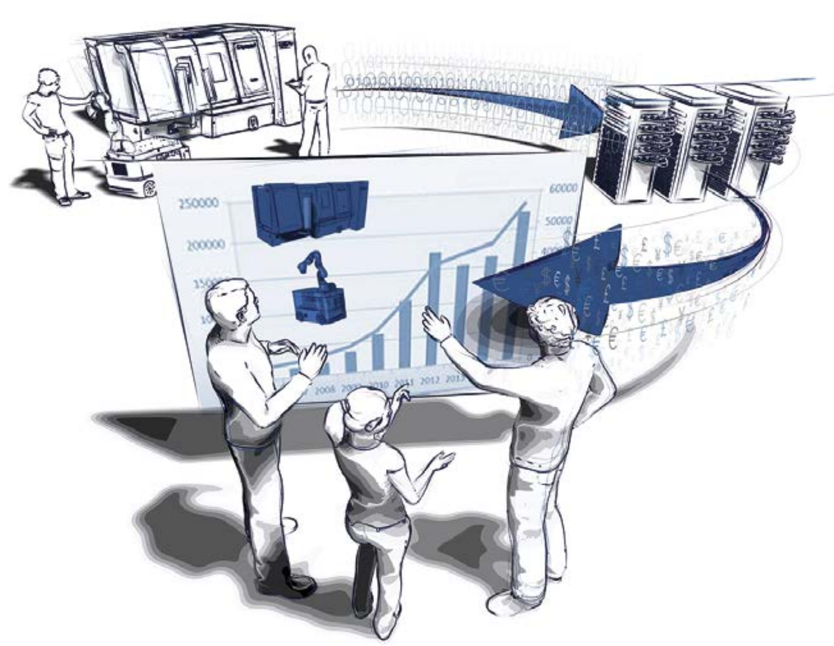

Fig. 3 Kubernetes can be used to control freely scalable production systems. (Source: M. Riedel / Internet of Production)

50 companies and associations are represented on the advisory board. They come from the automotive and aerospace industries, mechanical and plant engineering, as well as from the software sector.

Both in the data center of RWTH Aachen University and at Fraunhofer ILT, the systems are in use and are continuously being refined. The automated distribution of software and analysis of applications in the USP laser systems works reliably. "In five minutes, we can implement the software and hardware connection for a new laser, including integration into the cloud-based environment," Kröger explains the current status. Research is currently being conducted into the automatic evaluation of measurement data. The goal is to combine data from as many systems as possible and have it graphically prepared for users. In the future, the process on the laser systems is to be optimized from the data in the field of artificial intelligence via machine learning.

The Cluster of Excellence "Internet of Production" (IoP) is funded by the German Research Foundation DFG. The first runtime phase started in January 2019 and will last seven years.

Participation opportunities

The cluster of excellence thrives on the exchange with manufacturers and users of the software. Currently, the system is in beta phase and the systems have all been rebuilt, therefore tooling has been kept to a minimum so far. Without appropriate software development, networking and Kubernetes knowledge, the use of the system is initially very limited for users. For this reason, the project partners offer consulting and training.

"Component manufacturers could also exchange information with us about the technology stack used, thereby simplifying their software or drivers for integration. If you provide us with the components, we could also support you in integrating the software into your system environment," Kröger says and adds: "For complete system manufacturers, a co-operation is interesting with regard to the use of the systems. Since we rely completely on opensource technologies, early alignment of system manufacturers with Kubernetes can be quite interesting in order to discover trends at an early stage."

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iop_rwth Cluster of Excellence „Internet of Production"

ed locally. Fraunhofer ILT developed the software "SliceGen" specially adapted to the laser structuring process. A CAD model is filled with tool paths layer by layer. Each layer can be tiled to the limited working volume of the laser scanner. The tiles can be distributed randomly to avoid visible boundaries. The software is also able to generate tool paths for form correction by measured data. For this application the tool paths for removing the surplus volume are calculated based on the desired and current topography.

For laser polishing, Fraunhofer ILT developed the software "TP4" to convert data, generated by a conventional CAM software (for finishing milling), into tool paths which are suitable for the laser polishing process. As in laser structuring, this process also uses a laser scanner for fast laser spot positioning. Therefore, the required total movement is split into two parts. The fast movement is assigned to the laser scanner while the slow movement is assigned to the slower mechanical axis system (usually a 5-axis system). The software calculates the superposed movement and generates separate NC programs for the laser scanner and the mechanical axes. Machine programming in work piece coordinates is also supported which allows the usage of a measuring probe.

Control of galvanometric laser scanners

For many laser-based processes it is advantageous to rapidly guide the laser beam focus over the surface with the use of galvanometric laser scanners with axes of very low inertia. In order to control these scanners, special controller systems with low cycle times are used. Many different software solutions for controlling laser scanners, which are often restricted for laser marking applications, are commercially available.

For an overview of Fraunhofer ILT's software offerings, please visit https://www.ilt.fraunhofer.de/en/media-center/brochures/brochure-software-tools-for-laser-material-processing-2017.html

Web-based design tool for better job safety

Safe human-robot collaboration

Source all images: Fraunhofer IFF

The safety of people interacting with robots has top priority, especially when humans and robots are working side by side instead of being separated from each other by safety fencing. The Fraunhofer Institute for Factory Operation and Automation IFF's web-based design tool helps companies design their cobots. The Cobot Designer helps minimize the risk of accidents and increases employee safety. The tool is available as a free web application.

Humans and robots are sharing workspace in more and more sectors, whether they be manufacturing, logistics or medicine. Safety plays a major role in this. Up to now, range-finders on robots have prevented severe impacts or crushing when collisions occur but these sensors do not function when humans and machines have to stand close to each other, e.g. in subassembly. This requires other solutions. Teams of Fraunhofer IFF research scientists have developed a web-based application, the Cobot Designer, which ascertains the robot speeds that ensure safe collaboration. The design tool helps programmers design cobots safely. The project was contracted by the German Social Accident Insurance Institution for the Woodworking and Metalworking Industries (BGHM).

Digital hazard prevention for cobotic workstations

Anyone acquiring cobots for their business must perform a legally required risk assessment. Companies must identify specific potential hazards and foreseeable misuse by employees beforehand. The maximum speed a robot is permitted to reach is measured when it is certified for safety. A special device measures impact forces and pressures that act on anyone who comes into contact with the robot. The limits from the standard ISO/TS 15066 may not be exceeded. Otherwise, the robot's speed would have to be reduced to prevent injuries to employees caused by clamping or impact. Such measurement is costly and requires expertise. The robot must be programmed and built. "Small businesses in particular can't afford this. What's more, measurements are taken too late since the robot has already been purchased. Our Cobot Designer for digital hazard prevention comes into play here," says Dr Roland Behrens, research scientist at the Fraunhofer IFF. Companies can use the interactive tool before a making a purchase to assess whether the robot's speed suffices to perform a particular job productively and, above all, safely. "The amount of force is contingent on the robot's speed," says Behrens. If limits

The Cobot Designer enables businesses to reduce their engineering work significantly when they are implementing their HRC applications.

Users can combine different robots, hazard situations and tools with the design tool, thus compiling and continuously expanding a catalogue.

are exceeded, productivity subsequently suffers. "Let us assume the robot has to presort a pallet in one minute. If the speed has to be reduced by fifty percent for safety reasons, the cycle time increases to two minutes, reducing the robot's economic efficienca fifty percent," explains the research scientist, adding, "That's why being able to perform an economic feasibility analysis before the purchase would be desirable."

Cobot Designer is intended to replace measurements with a tester

The Cobot Designer prevents bad purchases and more potentially necessary measurements. Using the design tool enables businesses to reduce their engineering work significantly when they implement future human-robot collaboration (HRC) applications. "The goal is to use computer simulation, as the Cobot Designer does, to dispense with measurements entirely in the future." The tool is available for free on www.cobotplaner.de to anyone designing an HRC workstation. The digital design tool runs on all browsers.

It is easy to use: The user merely has to enter the parameters for the robot, the hazard and the tool used, e.g., a gripper. Then, the Cobot Designer automatically computes the effect of contact between a human and the robot as well as the robot's maximum permissible speed. The tool also provides the option of loading proprietary, custom robot models. Parameters no longer need to be entered then.

Various biomechanical robot and hazard models constitute the technological basis. The user can combine different robots, hazard situations and tools, thus compiling and continuously expanding a catalogue. All the data entered can be downloaded and reused at a later time. Inputs are not stored on the Cobot Designer's server to protect data.

Stress tests with subjects deliver data for the biomechanical model

The biomechanical model precisely simulates the extent to which clamping and impact stress a person. It comprises all twenty-nine relevant body parts where a person can feel pain, including the head, for instance. This model draws from the results of the one and only human subject study in the world to ascertain biomechanical limits, which was conducted by the Fraunhofer IFF and contracted by the German Social Accident Insurance DGUV and the BGHM. The Fraunhofer IFF validated the results of the Cobot Designer's simulation experimentally in stress tests with human subjects together with physicians from Otto von Guericke University Hospital's Traumatology Clinic and with the involvement of the appropriate ethics commission. These tests ran from 2015 to 2019.

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Deeper insights, better designs – less prototypes

How state of the art multiphysics simulation helps to understand, predict, and optimize photonics processes and devices

Phillip Oberdorfer, Yosuke Mizuyama, and Christopher Boucher

Source: Shutterstock / Denniro. All other unless noted: Comsol

Numerical simulation of optical components and photonic devices is an essential step in the design of new products and the optimization of existing designs. Fast and cost-effective simulation can substantially reduce the amount of experimentation and prototyping required in the product development cycle.

The COMSOL Multiphysics software is used to perform numerical simulations in all areas of research and industry. The software is used to model physical processes – including high- and low-frequency electromagnetics, electrostatics, fluid flow, heat transfer, and structural mechanics – by numerically solving the partial differential equations that govern them.

It is possible to solve an arbitrary number of equations seamlessly and simultaneously, including all relevant dependencies between these equations. For example, users can model the focusing of light in a lens system while including the effect of temperature change on the refractive indices of the lenses, or even how thermal stress will deform the lens surfaces, all within the same model. The optical system can thus be simulated holistically and under real-world conditions.

Optical components and photonic devices can span a broad range of different sizes, from sub-wavelength geometries to propagation distances millions of times longer than the wavelength. The underlying equations that describe electric and magnetic fields are Maxwell's equations; different formulations and simplifying assumptions are then invoked, depending in part on the size of the simulation geometry. The software includes dedicated add-on products for electrostatics and magnetostatics, current flow, electromagnetic wave propagation, and optical ray tracing. Therefore, this software offers a suitable numerical method for electromagnetics simulation of any geometry size and any range of wavelengths or frequencies.

No matter what equations are being solved, the model building workflow with this software and the user interface is always the same. Once a simulation engineer has finished setting up a model, for example, to analyze parabolic solar

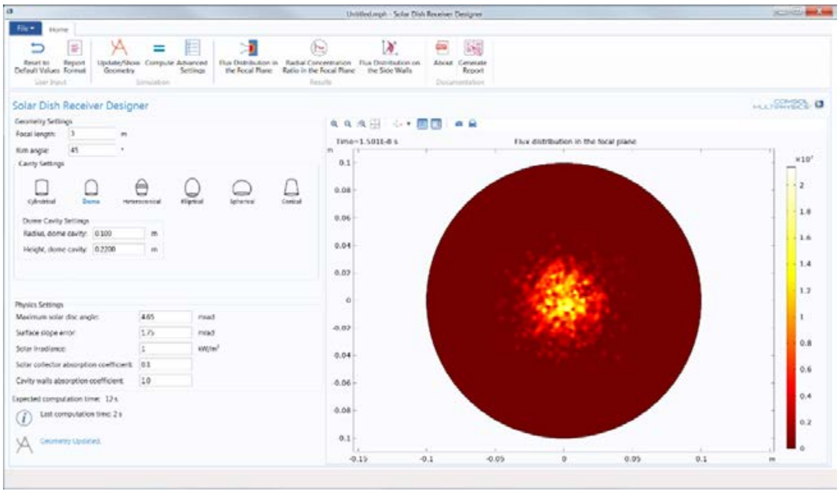

Fig. 1 The solar dish receiver model, turned into a simulation application, is more accessible for designing solar dish receivers without knowing the background physics.

dish mirrors, they can add a custom user interface to the model with little effort. This user interface can allow specific input values, such as the focal length of the mirror or the solar irradiance. The resulting simulation app is typically self-explanatory and user friendly, so that the designated user of the app does not need any simulation knowledge to model and produce new results. The simulation app can be shared as a completely standalone program. Thus, all departments of a company benefit from the added value of simulation when the simulation department produces apps.

Full-wave simulation extends the range and depth of lens analysis

In addition to the optical lenses found in cell phones, laptop computers, and more, we are surrounded by items processed through optical lenses every day. For example, many of the logos and other graphics seen on hardware devices, including cell phones and computers, are inscribed by a laser, or cut out by a high-power laser, in which case a laser beam had passed through many lenses. The same is true for food package date markings, markings on medical devices, and the so-called jamb stickers seen on car doors. As a result, we indirectly benefit to a great extent from computational lens analysis, without even knowing it.

Before such lenses are used in the real world, a number of computer simulations are typically performed. While simulation does not replace testing, it can help reduce the number of prototypes needed and also provide valuable insight to conduct better experiments. For the simulation of lenses, different methods are available, ranging from traditional lens-design methods to simulations that solve the full Maxwell's equations. But what might go into the decision to perform a lens simulation using one method over the other?

For the purpose of this article, lens simulation can be divided into two categories: design and analysis. Design here means optimizing a lens for a particular application, whereas analysis means gaining a deeper understanding of what is going on in the lens system.

For lens design, one tries to find an optimal shape of a lens so that it delivers the beam in a desired way; put another way, to make sure the lens focuses or diverges the beam appropriately. The goal of lens design is usually to minimize the optical aberration. Simulation can be used to achieve an optimal lens design, and this is a standard application of optics simulation. For the purpose of lens design, a simulation is usually carried out by a ray-tracing method for reasons of computational efficiency.

In a ray-tracing simulation, the electromagnetic waves are approximated by rays. The drawback of this approach is that diffraction effects are not included. However, in many cases, understanding the diffraction effects is not critical for the design. When diffraction effects are important, wave-optics methods that solve for the full set of Maxwell's equations without inherent approximations, other than the numerical ones required to fit the simulation in digital form on a computer, are used. When does one use wave optics instead of ray tracing for lens simulations? As it turns out, it is useful for both design and analysis.

In lens design, one of the important characteristics of the lens is the spot size. Ray tracing cannot simulate a focused beam because it is the result of diffraction effects. The detailed simulation of diffraction requires a full-wave optics simulation. To cope with this, ray tracing software often comes with some wave optics simulation tools, such as Fourier transformation and methods based on Huygens theorem and Fresnel diffraction. These three methods are sometimes collectively called physical optics. The formulas used are derived from an approximate theory and typically find a scalar electromagnetic field solution, which is good enough to design the beam size in many cases.

In lens analysis, physical optics may be adequate, but sometimes a more rigorous theory – specifically, Maxwell's equations – are needed to obtain the full vector representation of the electromagnetic fields. This methodology is sometimes called the full-wave method. High-numerical-aperture lenses require a full-wave approach to be accurately analyzed; the physical-optics methods are not applicable for analyzing fast lenses.

Company

Comsol Multiphysics GmbH

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With COMSOL simulation software, special emphasis is placed on the seamless simultaneous usability of all add-on products. Furthermore, COMSOL users have the ability to extend their simulation models into standalone simulation apps.

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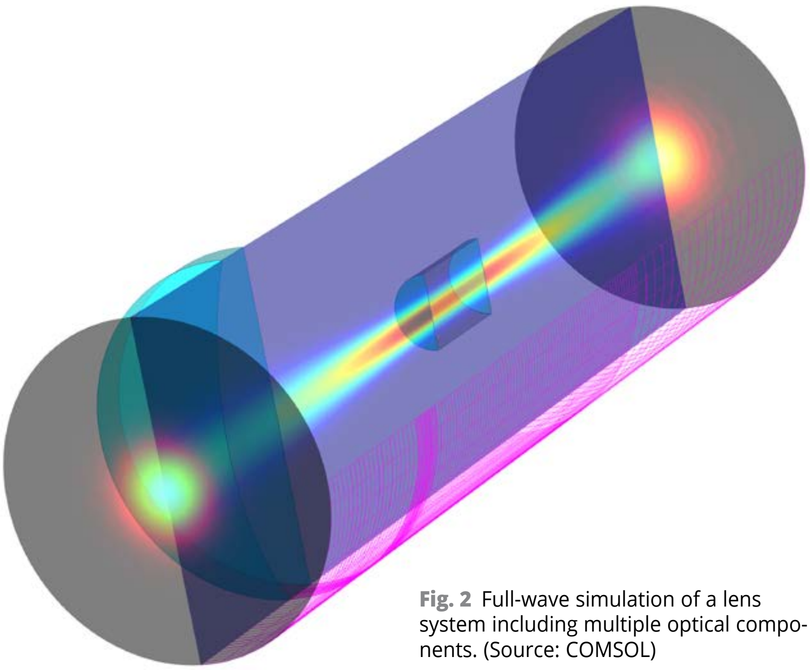

Fig. 2 Full-wave simulation of a lens system including multiple optical components. (Source: COMSOL)

When polarization matters or when the material has some anisotropic properties, a full-wave analysis is needed instead of scalar approximations. It is rare that a lens itself has such complicated properties, but it is also rare that the system being analyzed consists of only a single lens; several other optical components are usually involved. If so, it may be best to simulate not only the lens, but also the surrounding optics together with the lens by the full-wave method if possible. Historically, full-wave methods were frequently so computationally demanding that they were impossible to use in practice.

In the physical optics case, once the field is known in one plane, the method can calculate the field in another plane wherever it is; that is, it does not require the information between the two planes as long as the space between them is uniform. Therefore, it does not need a volumetric mesh in its computational domain.

On the other hand, the full-wave approach needs to solve for Maxwell's equations in the entire domain. A very powerful numerical method for this purpose is the finite-element method, in which the domain is meshed; it is subdivided into small elements having a simple shape. The maximum mesh element size is limited to a fraction of the wavelength to satisfy the Nyquist criterion. The shorter the wavelength, the smaller the finite element mesh element size. A smaller element size means a greater number of finite elements are needed and with that comes greater computational resources in terms of computational time and memory.

The physical optics methods typically find an outgoing wave field as a solution neglecting any reflections. This is how the physical optics formulas are derived. Compared to this, the full-wave method finds a solution that automatically includes reflections if there are any. If there are any material interfaces in the simulation model, Maxwell's equations will not give an out-going wave field only, since it is not the real solution. The real solution is the coherently combined out-going wave field and the reflections from the material interfaces.

There are three reasons why lens simulations using the full-wave method are difficult:

Mesh. Keeping in mind that the full-wave approach requires a mesh and the mesh size needs to resolve the wave, one can immediately understand how difficult it is to simulate a lens with the full-wave method. If the size of the lens and the focal length are of millimeter-scale range, for example, the domain size can be a thousand times the wavelength. Then, the number of mesh elements will be in the billions, so a regular computer cannot handle it.

Refractive index. Usually, any optical component has a refractive index higher than one – say, 1.5. Then, the wavelength in the optical component is 1/1.5 times the wavelength, which is shorter than the wavelength in the vacuum. This again increases the number of mesh elements, thereby further increasing the computational demands.

Interference. Any optical component has material interfaces, where the Fresnel reflection takes place. There is a 4 % reflection from a material surface of a refractive index of 1.5 for a beam of normal incidence. This reflection causes an interference with the incident beam, resulting in a fringe with the periodicity of one half of the wavelength. The mesh needs to resolve 1/2 times the wavelength. Combining with the refractive index effect, 1/3 times the wavelength needs to be resolved in the case of an index of 1.5; that is, the situation is three times worse for lens simulations than simulations in the open space, which is already difficult.

From the above discussions, it sounds like it is almost impossible to simulate lenses. However, using the full-wave method, we have the following two remedies at our disposal:

Beam-envelope method. Instead of solving for the fast-oscillation electric field, the slowly varying envelope function can be solved for if the wave vector is known. This is called the beam envelope method. In this case, there is no theoretical approximation, but it is equivalent to solving Maxwell's equations. In this formulation, the mesh needs to resolve the envelope function rather than the field itself. The number of mesh elements is greatly reduced if the envelope function is slowly varying, which is the case in practice for many lens simulations.

Antireflective (AR) coatings. Even with the beam-envelope method, the interference fringes do not give the designer a free pass because the envelope function is no longer slowly varying in the fringes. To remedy this, one can use an AR coating. It is possible to mimic a material interface with an artificial phase jump, which artificially generates a destructive interference with the incident beam and ends up with no fringes. Introducing this artificial AR coating can be motivated, since optical components are AR-coated in almost all practical cases.

COMSOL Multiphysics has these remedies available as built-in functionality. The Beam Envelopes interface of the Wave Optics Module is made with the beam-envelope formulation and includes the Transition boundary condition, which can be used as an AR coating. Full-wave lens simulations are therefore possible in a straightforward fashion by using a combination of the Beam Envelopes interface and the Transition boundary condition. It is possible to simulate slow lenses quite easily, whereas the simulation of fast lenses is more computationally demanding due to the fact that a finer mesh is needed. Fast lens simulations are still possible with a powerful-enough computer.

Full-wave simulations for multicomponent optical systems have previously been out of reach. However, using the methods outlined in the article, an entire optical system, including lenses and other optical components, can be simulated, provided the AR coating approach is applicable. In addition, full-wave simulations make birefringence analyses possible so that it can be used for the simulation of not only lenses, but also liquid crystals or second-harmonic generation (SHG) optics, including the lenses. Full-wave simulations performed in this manner extend the range and depth of lens analysis.

Structural-thermal-optical performance analysis: the quintessential multiphysics model

Numerical simulation has become an indispensable tool for the design, optimization, and diagnostics of optical systems. A high-fidelity computational model can greatly cut down the amount of time and effort spent on prototyping and related experimental work.

The task of setting up a high-fidelity model becomes more challenging for cameras, telescopes, spectrometers, and similar devices operating in extreme environments. This challenge is perhaps most daunting for optical systems on spacecraft. The environment of space can subject equipment to extreme temperature gradients, from the cold vacuum of space itself, to the overwhelming heat of the Sun, and everything in-between.

Changes in temperature directly affect the performance of an optical system because most real-world materials have temperature-dependent refractive indices. In addition, thermal stresses combine with other applied loads to cause deformations that can further degrade performance. Here we will explore some of the unique challenges of using simulation software for coupled structural-thermal-optical performance analysis, or simply STOP analysis.

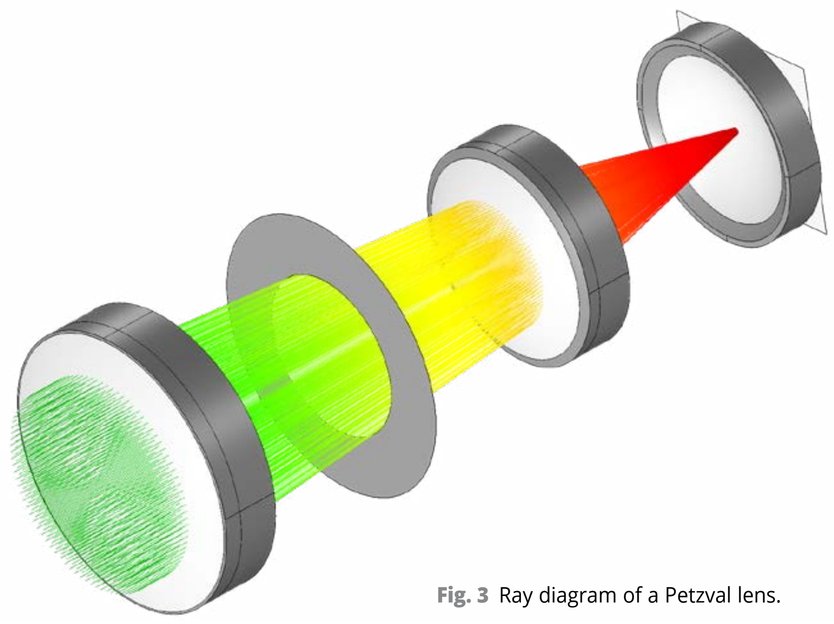

Fig. 3 Ray diagram of a Petzval lens.

Let's first consider a Petzval lens system at uniform temperature and with no applied forces. The Petzval lens consists of front and rear lens groups followed by a field flattening lens. Collimated rays propagate from the left (green) towards an image plane at the right (red, Fig. 3). Also shown are the image plane and an aperture stop between the lens groups.

Now suppose we take this simple lens system and insert it into a real-world assembly with stresses and temperature gradients. To perform an accurate STOP analysis we must not only model the lenses themselves, but also the surrounding apparatus. This requires us to consider the following questions: How are the lenses mounted? What are the boundary conditions for the structural analysis? What are the boundary conditions on temperature?

To demonstrate this workflow, we modified the previous Petzval lens geometry by mounting the lenses in a barrel inside a thermovacuum chamber, which aims to mimic the environment of space by regulating both pressure and temperature. A diagram showing a cross section of the lenses, barrel, mount, and chamber is shown in Fig. 4. Such a chamber might be used to test a camera or telescope at a low temperature in a controlled laboratory environment before launching it into space.

The entire barrel is contained within the thermal shroud boundaries (1) which are, in this example, held at a low fixed temperature of -50 °C, perhaps by pumping a liquefied gas through the walls. Radiation then enters the thermal shroud through an exterior vacuum window (2) and additional thermal window (3). This extra thermal window is in place to help regulate the temperature gradient in the lenses. The ambient surroundings outside the thermal shroud are at the laboratory temperature of 25 °C.

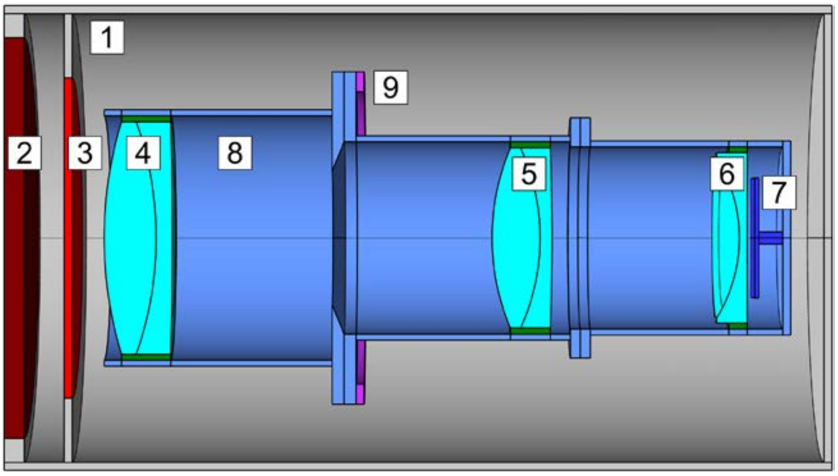

Fig. 4 Schematic of the Petzval lens assembly with added barrel and thermovacuum chamber

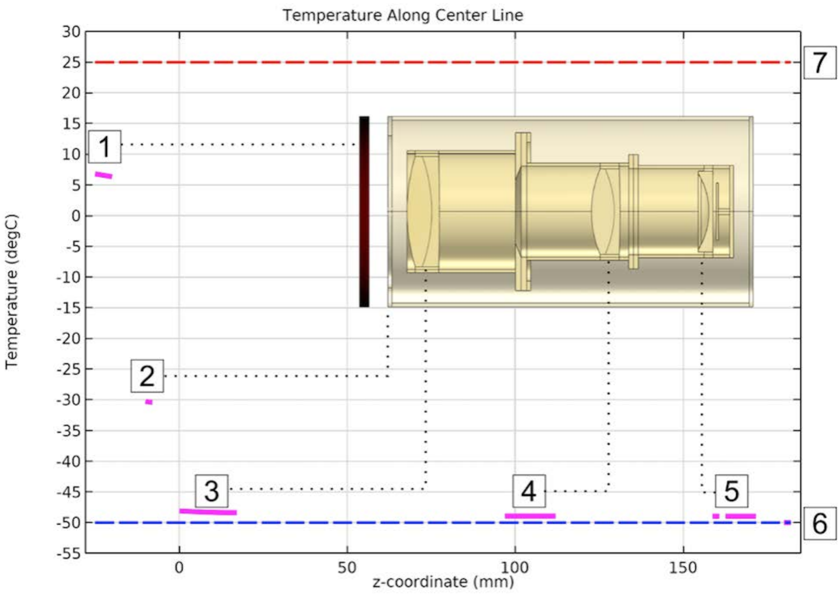

Fig. 5 The temperature in a cross section of the lenses, barrel, and thermal shroud.

Also shown are the lens groups (4, 5, and 6), the image plane (7), barrel (8), and a rigid support (9) where the displacement is assumed to be zero. The quantities being solved for include the temperature throughout the lenses, barrel, and windows; the structural displacement in the lenses and barrel; and the ray paths through the system.

STOP analysis requires a combination of numerical methods

From a mathematical point of view, STOP analysis is uniquely challenging because the structural and thermal models require a different type of numerical approach compared to the optical model. The most robust and flexible approach to structural and thermal simulation is the Finite Element Method (FEM). This method involves representing the geometry as a number of discrete numerical cells, or elements, and then approximating the strain and temperature in each element as piecewise functions defined on that element.

The optical performance is best predicted using a ray tracing approach. This is because FEM implementations of optical simulation usually require a mesh fine enough to resolve individual wavelengths, and this requirement isn't practical for optical frequencies.

If the structural and thermal simulations are performed on a discretized representation of the geometry using FEM, and the optical simulation uses a ray tracing approach, how do we factor in the effect of structural deformation and temperature change on the optical performance? The COMSOL Multiphysics simulation software provides a seamless integration of these different numerical methods within an all-encompassing user interface, which also includes tools for geometry setup, meshing, solvers, postprocessing, and much more. Its newest version, 5.6, includes dedicated tools for coupled STOP analysis and several new examples.

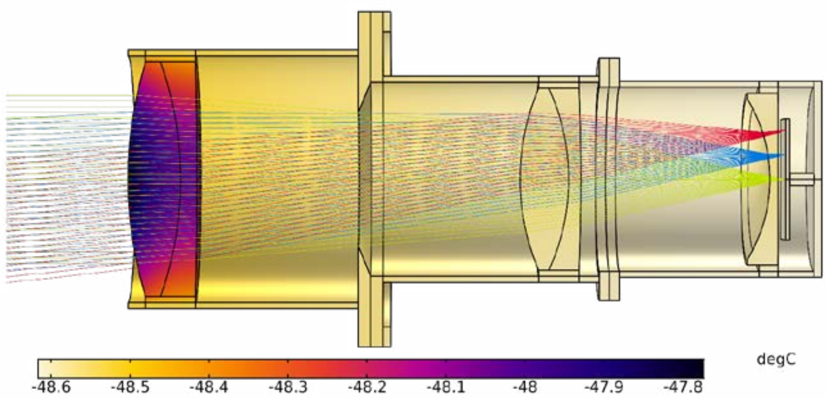

Fig. 6 Ray diagram of the heated Petzval lens assembly and barrel for three field angles

Assumptions for thermal simulation

The radiation entering through the vacuum window and thermal window has a broad spectral range. At the optical frequencies, we assume that light gets refracted by the lens; but in the infrared regime, we assume that the lenses are opaque, meaning that they absorb the incoming radiation and then reemit it diffusely in all directions. Therefore, the radiation entering the chamber actually requires two different modeling approaches to be used in tandem. In the optical regime we use ray tracing to observe the focusing behavior, while in the infrared regime we model the thermal radiation in tandem with conductive transport through the lenses and barrel assembly.

Using multiphysics simulation, the most accurate way to model thermal radiation (assuming ideal diffuse surfaces) is with the radiosity method. Thus the thermal model combines the radiosity method to model surface-to-surface radiation with the finite element method to model conductive transport through solid bodies. There is no convective transport to worry about because the lenses and barrel are in a vacuum.

Ray tracing in a deformed geometry

The ray tracing algorithm automatically accounts for thermo-optic dispersion and optical stress. The rays interact with a mesh representation of the boundaries in a geometry rather than their analytic representation, and this makes it very convenient to model reflection and refraction by a deformed geometry because the displacement field in each boundary element is known from the FEM simulation. In other words, the same mesh is used to assign degrees of freedom in a FEM calculation of the structural displacement and temperature, and to query the position and normal direction at ray-boundary interactions.

To account for thermo-optic dispersion, the rays can query the temperature field at any location within a lens. This temperature and the ray's vacuum wavelength are used to compute the refractive index encountered by each ray.

Altogether, multiphysics modeling enables us to simultaneously do the following:

- Model conductive heat transfer and structural deformation using FEM,
- Model radiative heat transfer between diffuse gray bodies using the radiosity method, and
- Trace light rays through the heated and deformed lens system.

The results of the thermal model demonstrate the importance of using an additional thermal window to regulate temperature in the Petzval lens assembly. Fig. 5 shows the temperature in a cross section of the lenses, barrel, and thermal shroud. Because the temperature change within the barrel is rather hard to see, the temperature is also plotted as a 1D graph along the center line of the assembly.

The outer window of the vacuum chamber (1) is the warmest because it is exposed to radiative heat transfer by the ambient surroundings (7). The thermal window (2) is about -30 °C, much colder than the surroundings but still significantly warmer than the thermal shroud (6). The lens groups (3, 4, and 5) are all within 2 °C of the thermal shroud.

This aptly demonstrates the need for a thermal window; without it, the temperature difference among the lens groups might be as high as 20 °C, rather than 2 °C, leading to significantly greater thermal stress. This is similar to the rationale behind using double-pane windows for room insulation.

Rays were traced through the thermally deformed system for three different field angles. The trajectories are shown in Fig. 6; the temperature field in the lenses and barrel is also shown.

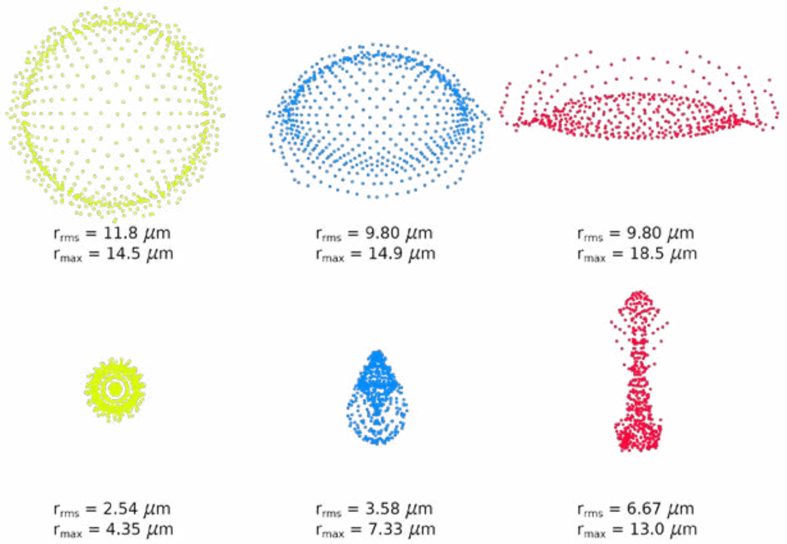

Fig. 7 Spot diagrams for the Petzval lens system in the thermovacuum chamber (top) and at room temperature (bottom).

A convenient way to compare the optical performance in this thermovacuum chamber and at room temperature (20 °C) is by creating spot diagrams, which show the distribution of rays in the image plane. Spot diagrams for each of the three field angles are shown in Fig. 7.

From the spot diagrams it is more obvious that the temperature change has a significant effect on optical performance; not only are the spots visibly different, but their root mean square (RMS) spot sizes differ significantly.

Using multiphysics simulation we are able to conduct a coupled STOP analysis within a single self-contained, simulation software package. Furthermore, the means for deploying numerical models to a larger user base have improved rapidly in recent years. The democratization of simulation, together with the ease-of-use of modern STOP analysis tools, suggests that the use of simulation in optical design will only become more essential and more widespread in the future.

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Mind the gap

Using thermal simulation software to analyze cooling mechanisms of pluggable optics modules

John Parry

Source all images: Siemens Digital Industries Software

Simcenter is a flexible, open, and scalable portfolio of the best predictive simulation and test applications that support you at every step in your digital journey. Simcenter is a key component within the Xcelerator portfolio, allowing engineers to generate a set of ultrarealistic, multiphysics models and data that can predict real product behavior. By providing insight into the real-world performance of a product or a process, Simcenter allows you to accelerate innovation over the entire lifecycle. As an example, this article examines work done by Terence Graham and Bonnie Mack at Ciena Corp. in support of IA# OIF-Thermal-01.0 IA that included a study of the thermal interface resistance between a CFP2 lid and heat sink base, including heat spreading effects.

Pluggable optics modules (POMs) are optical interface devices connected to the throughports in the faceplate of a printed circuit board (PCB). They combine fiber-optic transmitters and receivers (transceivers) and some signal processing into one package. The transmitter side converts an electrical signal into light for transmission over optical fiber while the receiver section converts the light signal into an electrical signal. The modules plug into connectors on the host board for additional signal processing, switching etc.

Today's high-power, higher bandwidth POMs are difficult to keep cool. The faceplate port is contained in a PCB-mounted cage: a folded, sheet-metal enclosure that is press-fit into the PCB to provide connector alignment and electromagnetic compatibility (EMC), cf. Fig. 1. The cage generally prevents heatsinking to the module bottom while providing an opening in the top surface where a spring-loaded riding heatsink can contact the lid. The challenge is to permit the required sliding while providing a low interface thermal resistance.

POMs extend through the faceplate and can be hot swapped. The nominal air gaps (0.2 to 0.3 mm) between the module case and the cage, and between the cage and PCB provide an inconsistent thermal resistance. The cages generally have small openings on the sides to allow ingress and egress of air for cooling. With high power POMs, these openings provide insufficient cooling, so an opening on the cage top is added, giving access for a spring-loaded, riding heatsink.

Another challenge to keeping these modules cool is that thermal inter-

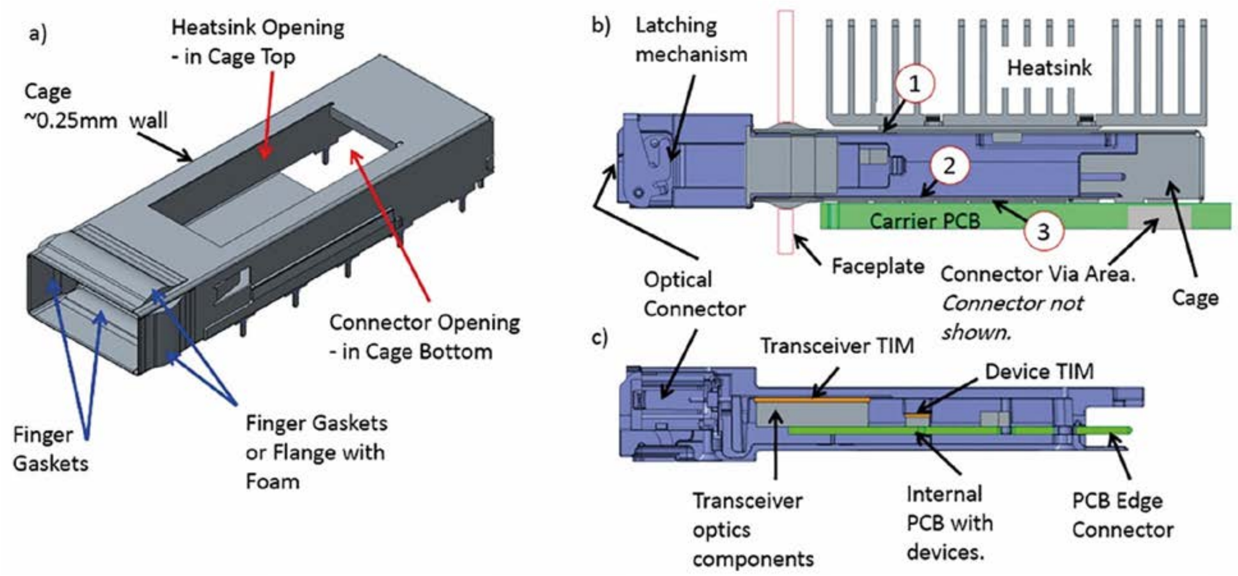

Fig. 1 Cage design and section showing typical internal layout. Narrow air gaps locations in image (b): module to top of cage (1), module to bottom of cage (2), bottom of cage to PCB (3), and, not shown, sides of module to sides of cage (4).

face materials (TIMs) cannot be used between the heatsink and the POM case because of their hot plug feature. As a result, a dry thermal interface between the two surfaces is used. In addition, the thermal interface between a pluggable optics module and heatsink is not consistently defined or controlled in the multisource agreements (MSAs) that specify the physical form factor and electrical interfaces to allow multiple manufacturers to make physically compatible products.

Allowing the required sliding while providing a low interface thermal resistance is especially important in a telecom environment where shelf-level products in network equipment building systems [1] must operate in an ambient temperature of 55 °C. The POMs' case temperature limit is usually 70 °C. This results in a 15 °C temperature difference required to cool the POMs. Fig. 1 shows the typical thermally important features of POMs and cages.

The Optical Internetworking Forum (OIF) [2] developed an implementation agreement [3] to specify general requirements for the thermal interface. The IA specifies that the MSAs define the location and size of the contact areas where most heat would be removed from high power modules and directly addresses the issue of removing heat from the top of the POMs [4–7]. It defines resistance parameters of the interface between the module and heatsink.

The IA also specifies the information POM suppliers must provide to facilitate thermal integration of the module within the host system for both the initial assessment and detailed design stages. These include specifications for temperature drop and thermal resistance between the module and an "ideal" heatsink. It defines a thermal interface resistance that includes interface contact and spreading effects. The IA recommends tighter tolerances for surface finish and flatness for well-controlled interfaces. It defines power density classes for the thermal interface and describes a method for measuring the thermal interface resistance between the module and a cold plate with an "ideal" mating surface.

Thermal interface resistance of a POM is affected by design factors under the control of both the system designer and the module designer. Surface finish and flatness have a strong influence within normally accepted manufacturing and machining practices.

Analyzing the thermal resistance between the POM and its case

Ciena Corporation conducted a study [8] to assess the thermal interface resis-

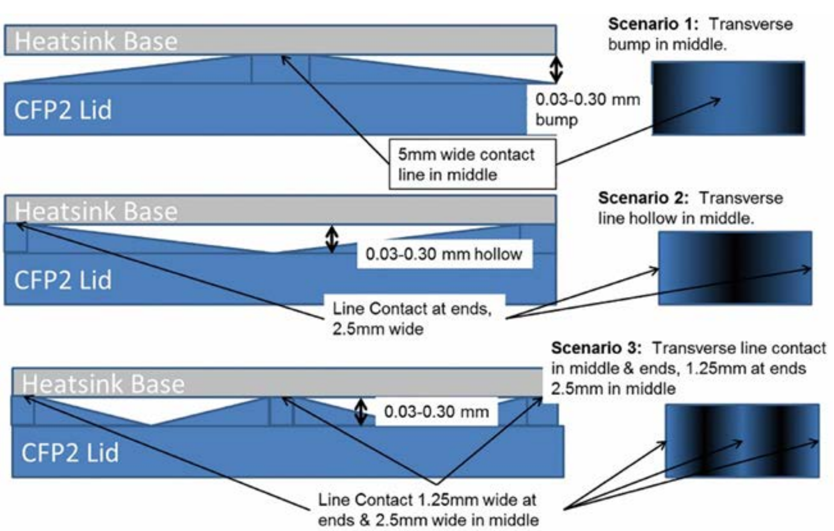

Fig. 2 The CFP2 contact interface flatness scenarios.

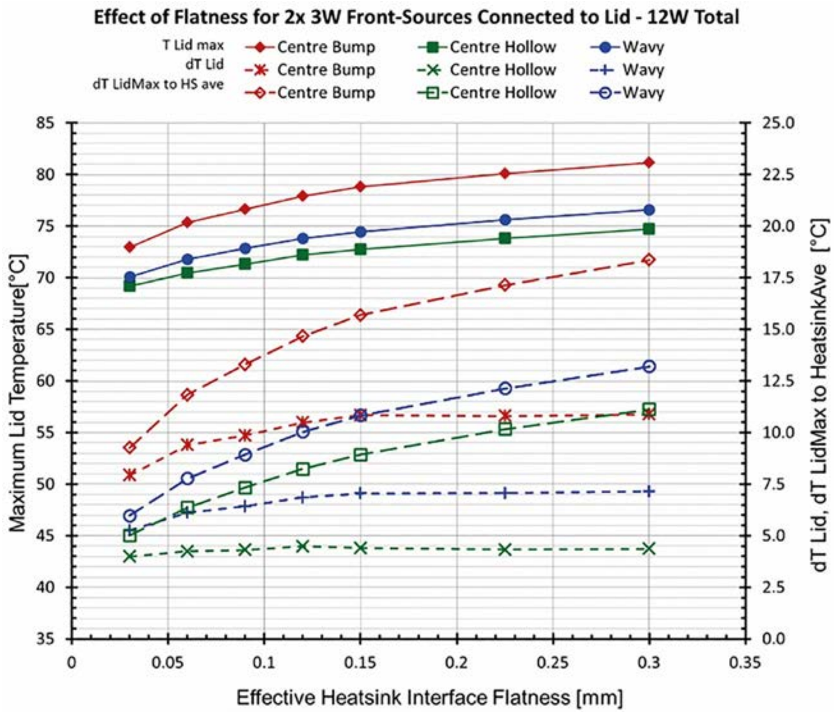

Fig. 3 The range of flatness results with front device and rear PCB heat dissipation (T Lid max = maximum lid temperature, THS ave = average heat sink pad temperature, dT Lid = temperature difference among lid locations, dT Lid max to THS ave = T Lid max – THS ave)

tance between a C-Form Factor Pluggable (CFP2) module lid and heatsink base, including heat-spreading effects. The study examined three contact scenarios (**Fig. 2**):

- a transverse bump in the center of the lid
- a transverse hollow in the center of the lid
- a transverse contact in the center and ends of the lid

All three scenarios have the same contact area. These simplified contact geometries and the contact gap ranges from what would be an extremely fine production surface flatness to 0.3 mm, the maximum allowed by the MSA for the CFP2 contact surface for Power Class 1 and 2.

For the study, the team conducted thermal analysis using the computational fluid dynamics (CFD), thermal-simulation software from Siemens, Simcenter Flotherm. They assumed both surfaces had the same type of flatness so that modeling of the net gap between surfaces could be easily implemented in the software.

The team modeled the resistance in the contact areas between the heatsink and the module using the method described in [9]. A simplified CFP2 software model was created that included a Type 6063 grade aluminum case and as many as six sources to dissipate power and to contact the lid.

Results were obtained for varying gaps because of out-of-flatness and different source locations. Intake air was set for 55 °C at 1 m/s across the enclosure cross-section upstream of the module. Total power for the CFP2 was 12 W in all cases. Other model details are given in [10,11]. CFP2 lid temperature was monitored directly above the center of each source.

Figs. 3 and 4 show plots of maximum lid temperatures versus net flatness over the range of 0.03 to 0.3 mm flatness for the three scenarios.

Spreading resistance in the lid was highest for scenario one, a center bump, which is effectively a single contact. Spreading resistance varies with the thermal conductivity and thickness of the lid. The interface resistance between the lid and heatsink was sensitive to the interface flatness. Temperature differences between the lid and heatsink base could be reduced by 5 to 8.5 °C with flatness improvement on a CFP2 depending on heat source location and the nature of the out-of-flatness. This is one-third to half of the CFP2 temperature budget in a NEBS environment –a huge improvement without increasing the size of the heatsink.

Why simulation and test tools are important for developing today's advanced technologies

An industry that looks toward the future is driven by innovation, striving to out-perform their competitors. Companies are faced with increasing complexity across multiple dimensions such as integrating mechanical, electrical, and controls behaviors, and incorporating new materials and manufacturing methods. Products can no longer be designed in isolation, which makes development even more complex to manage. Engineering teams are faced with tradeoffs that can seem impossible to solve: making products more powerful but consume less energy, making them thinner, yet cooler. How do you navigate these tradeoffs and answer the tough questions to bring innovations to market faster, despite the increased complexity?

Answering this question requires solutions that can help predict and improve product performance. Simcenter, a key part of Siemens Xcelerator digital software platform, is a flexible, open, and scalable portfolio of the best predictive simulation and test applications that are designed to drive innovation into your products and shorten time to market. The portfolio covers the full breadth of methodologies for engineering, covering system simulation, mechanical simulation, CFD simulation, electromagnetics and electronics cooling, and physical testing. These different domains of engineering are augmented with design exploration and analytics, workflow automation, and simulation process and data management. Customers who use Simcenter are supported by highly skilled and experienced staff who provide engineering services, deliver deep

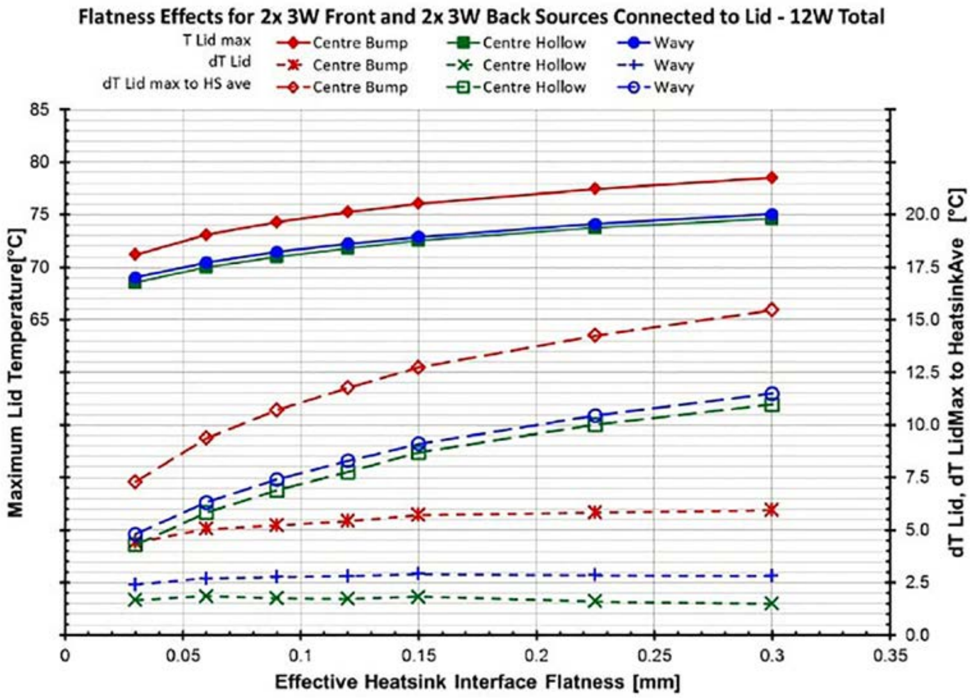

Fig. 4 The range of flatness results with heat dissipation on front and rear devices with 0 W PCB dissipation.

industry expertise and know-how, and offer dedicated support. But why it is important to invest in simulation and test tools?

For modeling complexity

Engineers need the ability to predict or measure behavior and performance in the best possible way. This means capturing all complexity in a product, from the geometry, the physics, or the usage environment, all of which affect performance. Greater accuracy leads to greater confidence in the predictions and therefore in the decisions. This is true at all stages of development, and using a combination of 1D and 3D simulation with test is the best way to model the complexity and reach the desired accuracy.

Simulation enables modeling the complexity all the way from material behavior to performance of entire systems, including a broad range of physics such as structures, flow, electromagnetics, motion, and thermal.

For exploring the possibilities

To truly gain an advantage from investments in modeling complexity, engineers need to leverage those models to run experiments. An increase in complexity also means an increase in the degrees of freedom available for adjustment. Through a systematic and intelligent exploration of the design space, engineers can gain tremendous value from the models, by discovering new designs, optimizing for performance, and improving robustness, all in a fraction of the time it would take without these software tools.

For faster production

The traditional pressures of time, cost, and quality still apply even as complexity increases. And increasing complexity can slow down ability to make the right decisions. Engineers need to be able to work faster and innovate more, despite the complexity with which they are dealing. Speed and productivity are always important at the individual, group, and enterprise levels, and having the right tools makes a world of difference.

For integration

Product development is increasingly complex, which means more opportunities for misalignment between teams. Yet development in different functional areas happens simultaneously. An optimal decision in one area could prove to be sub-optimal for another and cause delays in development, design rework, or even field failures. Balancing tradeoffs between performances is crucial but it can only be achieved by having everyone aligned. Traceability is key to enable visibility and audits on how decisions were made and who is impacted. Staying integrated means having a digital thread provided by the software solutions that connects all relevant stakeholders, models, and data.

Conclusion

The OIF agreement [3] specifies information required by system designers for preliminary, simplified system, and detailed system analyses. Simple estimations of the temperature loss to the heatsink are feasible by defining power density classes and requiring a measurement of the overall thermal resistance between the monitoring point on the POM module lid and the heatsink. This measurement is to be done on a module in its cage and powered from an insulated carrier PCB with a cold plate heatsink to ensure the thermal interface resistance measurement includes the POM's contribution to the interface resistance.

For this environment, the results presented here show that 99 % of the CFP2 dissipation flows through the interface of interest, whereas other test methods have net heat transfer from the POM to the carrier PCB, or to the POM from the carrier PCB.

Comprehensive thermal digital twin for a POM can be created with a computationally expensive detailed model either built by the system designer with information from the module supplier or a model supplied by the module vendor. For example, it could be used further in the development of a Delphi-type resistance network or a Boundary Condition Independent Reduced Order Model (BCI-ROM). A comprehensive digital twin could be used to analyze the connections to the PCB, surrounding air, and heatsink with distributed internal heat sources like that used for multi-junction integrated circuit devices.

To find out more about Simcenter and Xcelerator, the latest in comprehensive and integrated portfolio of software and services, visit Siemens Digital Industries Software.

*

The article is based on original work by Terence Graham and Bonnie Mack, both senior thermal engineers for Ciena Corporation.

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[1] Telcordia Technologies Generic Requirements, Generic Requirements for Telecommunications Data Center Equipment and Spaces, GR-3160-CORE, Issue 2, July 2013.

[2] OIF website location: www.oiforum.com

[3] IA# OIF-Thermal-01.0, Implementation Agreement for Thermal Interface Specification for Pluggable Optics Modules, Optical Internetworking Forum, May 18, 2015.

[4] *K. Hiramoto:* Hardware Technical Editor, CFP MSA CFP2 Hardware Specification, Revision 1.0, July 2013, www.cfp-msa.org

[5] *H. Oomori:* Hardware Technical Editor, CFP MSA CFP4 Hardware Specification, Revision 1.0, August 2014, www.cfp-msa.org

[6] SFF Committee, SFF-8663 Specification for QSFP+ 28 Gb/s Cage (Style A), Rev 1.5 April 2014, ftp://ftp.seagate.com/sff

[7] SFF Committee, SFF-8661 Specification for QSFP+ 28 Gb/s 4x Pluggable Module, Revision 2.0, February 2014, ftp://ftp.seagate.com/sff

[8] *T. Graham, B. Mack:* Pluggable Optics Module – Thermal Specifications, Electronics Cooling, September 2016.

[9] *M. M. Yovanovitch, J. R. Culham,* and *P. Teerstra:* Calculating Interface Resistance, Electronics Cooling, Article 3, May 1997, http://www.electronics-cooling.com/Resources/EC_Articles/May97/article3.htm

[10] *B. Mack, T. Graham:* Thermal Specifications for Pluggable Optics Modules, 32 IEEE SEMI-THERM Symposium, March 2016.

[11] *B. Mack, T. Graham:* Pluggable Optics Module – Thermal Specifications, Part 1, Electronics Cooling, June 2016.

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Preview

Full article online and in PhotonicsViews issue 5 / 2021

Adjustable ring shaping for laser welding applications

A diffractive method for shaping a laser into a spot surrounded by a ring, with continuously adjustable power ratio

Source: Shutterstock / Alexander Tolstykh

The recent increase in availability of high power NIR fiber lasers at affordable costs has resulted in such that practically the power is no longer the limiting factor to laser welding speed. Instead, other physical phenomena such as spattering, humping and weld porosity became dominant at high weld speeds. These phenomena have shown to be substantially minimized when using a special illumination power consisting of a concentric ring and spot. However, the optimal power ratio between the spot and the ring differs between different welding process parameters and different system setups, and so an adjustable ring-to-spot ratio enables the system manufacturer to find the optimal work point for each process.

In order to address this demand, Holo/Or has launched a beam shaper for controlled adjustable ring-to-spot ratio, a diffractive-shaping solution which consists of two identical diffractive optical elements (DOEs) placed on the same optical axis which, when rotated against each other can shape the beam which propagates through them in a range from where 100 % of the power is in the central spot and continuously transferring a portion of the energy to the outer ring until ~80 % of the power is in the surrounding ring with no energy at the central spot.

These elements can easily be installed into off-the-shelf, manual or motorized, rotational mounts to create an optical module, which can be integrated in multiple configurations onto the optical axis, requiring no high NA or other costly optics different than the standard laser welding optics. The solution can be used with both single mode and multimode lasers, and can be adapted for large beams typically used with multi-kW lasers, thus enabling a large range of macro and microwelding processes.

Holo/Or

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Metrology & Industry 4.0

Deploying optical technology and process control solutions to the smart factory floor

Peter J. de Groot & Michael Schmidt

Source all images: Zygo

When looking at the place of metrology in the 'fourth industrial revolution', it is interesting to ponder whether industry 4.0 is being driven by developments in metrology or metrology developments are being driven by Industry 4.0.

▲**Fig.1** The future of advanced manufacturing relies on greater integration of precision metrology with production quality control.

Today's most sophisticated metrology systems drive quality assurance (QA) which has become a fundamental digital task which in and of itself facilitates efficient and cost-effective production processes. In a very real sense, QA data today controls how products are made, and drives the bottom line and the repeatability in production which is vital in all pan-industrial manufacturing scenarios.

From this perspective, it is a short leap to advocate that QA drives Industry 4.0. The dynamic growth of non-contact 3D optical metrology solutions in recent years reinforces this argument, as image processing and vision systems easily fit into Industry 4.0 processes.

And so we begin to shift preconceptions. For a long time, metrology for production QA has been seen as akin to a necessary evil, a part of the product development process that ticks boxes, but doesn't directly add value. From this angle, it can be argued that metrology serves no other purpose than to catch failures within a production process. If the failures or short comings were not there, then the role of metrology would be redundant.

Company

Zygo Corporation

Zygo Corporation is owned by AMETEK, Inc., a leading global manufacturer of electronic instruments and electromechanical devices with annual sales of approximately $5 billion. ZYGO is a worldwide supplier of optical metrology instruments, high-precision optical components, and complex electro-optical systems, and Its products employ various optical phase and analysis techniques for measuring displacement, surface shape and texture, and film thickness. Electro-Optics and Optical Components businesses leverage ZYGO's expertise in optical design and assembly, and high-volume manufacturing of precision optical components and systems, for the medical/life sciences, defense and industrial markets.

www.zygo.com

But in the modern world, metrology is the source of bucket loads of data, which can be used to fuel the systems used in a smart factory or Industry 4.0 environment, promoting true data-driven production.

Drilling into Industry 4.0

A key competitive driver for manufacturers today is efficient production, which is why Industry 4.0 solutions using digital technologies to stimulate innovation and improve production processes are gaining traction across all key industrial sectors. As these technologies are enhanced and become less expensive, as a trend, Industry 4.0 will become more and more important.

The underpinnings of the concept of Industry 4.0 requires that businesses interrogate their competitive model and focus on increasing capacity to deliver more cost-effective products through the digitization of the entire production process.

Today, this requires that these businesses completely re-assess their entire value chains, and apply different ways of thinking and toolsets, fusing the physical, digital, and virtual worlds together. Industry 4.0 encourages the integration of intelligent production systems and advanced information technologies, and is fundamental to the foundations and future of many of the world's leading manufacturers.

The promotion of a digital manufacturing strategy is fundamental for many manufacturing companies if they are to remain competitive in the years to come. and central to this is the capture, analysis, and alteration of data. From this perspective, the role of 3D metrology solutions is clear, and it is very much more than just catching the occasional QA failure in production.

The power of metrology-driven data

For Industry 4.0, use of big data is key, as is its movement and use upstream and downstream in the product development process, with algorithms adjusting the manufacturing process to ensure consistent, efficient, and above all repeatable production with zero failure rates. 3D data captured as parts are manufactured using fast, non-contact optical metrology systems can be directly fed to the quality control team who can analyse its conformance with design intent by comparing it with 3D CAD solid models. Any areas of concern can be highlighted, and adjustments can be made instantaneously to CAM files.

Such an automatic process all but negates the need for shut-off, drastically reduces failure rates and scrap, and therefore enhances the overall efficiency and cost-effectiveness of production. In such a scenario, advanced 3D optical metrology solutions enhance the quality, quantity, and speed with which data is collected, and allows its analysis and significance to be assessed in the blink of an eye to the betterment of manufacturing processes.

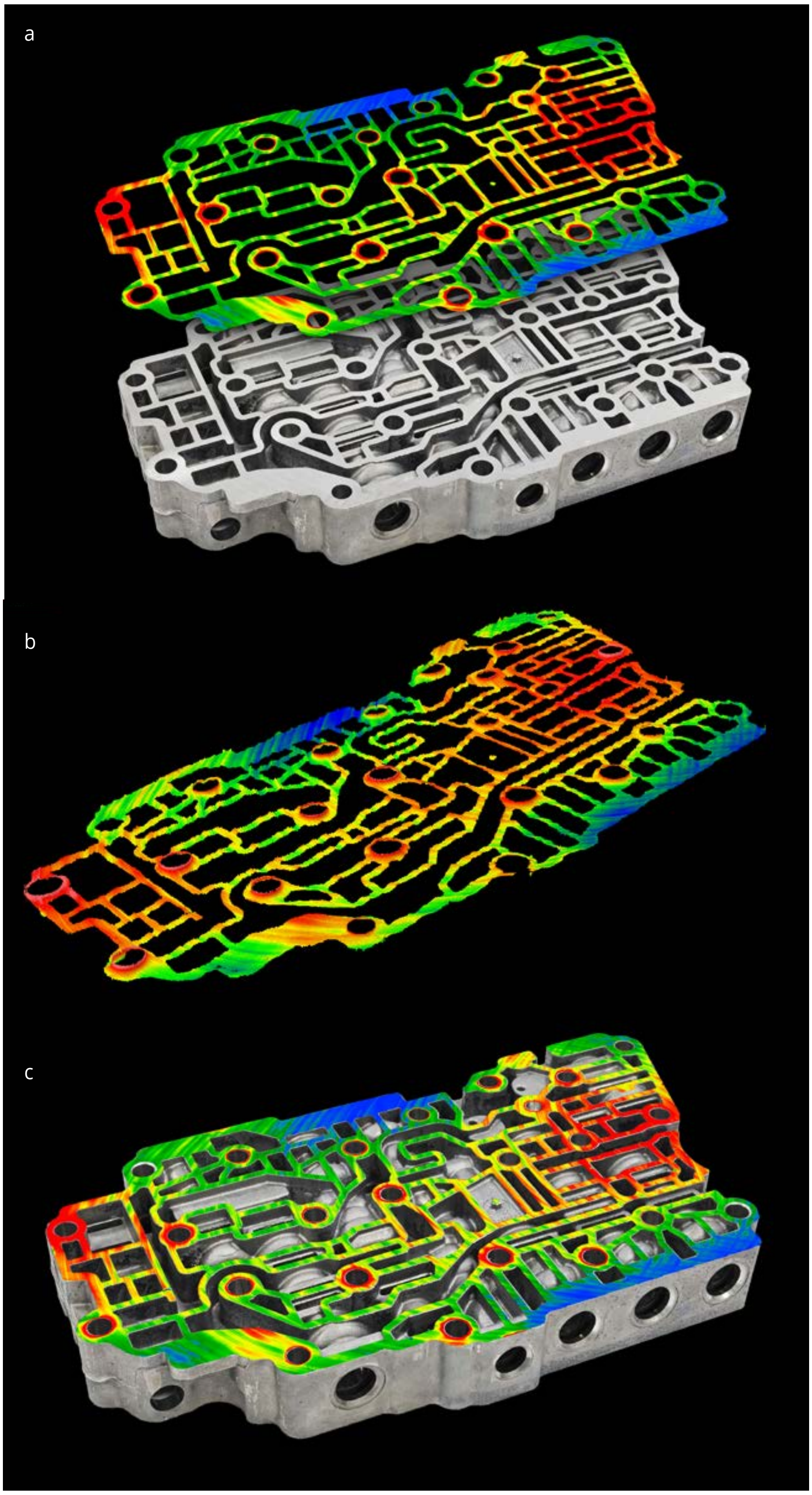

Fig. 2 a – c Topography of a valve body for an internal combustion engine, measured over a 200 mm × 100 mm area using multiple image captures with interference microscopy

Smart factory metrology solutions

Metrology's role in highly digitized factories that continuously collect and share data through inter-connected devices, machines, and production processes is to support digital production at every stage. To achieve the objectives of the "smart factory," manufacturers must evolve their processes to close gaps in inspection-related data at every stage in the production value map. It also has a role in giving manufacturers greater visibility of the entire supply chain, including suppliers. Smart factories bristling with industrial robots and automated handling systems rely disproportionately on fully automated control systems and speedy verification and feedback.

This plays to the use of in-process metrology solutions and non-contact 3D optical solutions.

Typically, the conversation when looking at the optimum use of metrology in advanced manufacturing settings today is between its use in the lab or in-process. Ultimately, a key driver for the shift from in-lab to in-process is a desire for a "faster time to data," and more importantly, the ability to make decisions as a result of that data faster. Hence, it is a key element of Industry 4.0 and the efficient running of a smart factory.

When compared to alternative legacy metrology solutions where measurement is a separate off-line activity, in-process solutions have a number of key advantages, the most obvious being the speed with which the data derived from it can influence decision making. If carrying out metrology in-lab, parts must be moved to the QC department, and then they need to be set-up for the metrology operation to be undertaken. If the metrology is in-line, various process steps are removed, and as defects and problems can be identified and rectified instantaneously reworking is reduced. In-process metrology therefore assists in preventing problems before they arise, and if they do arise allows them to be identified and addressed before they become a costly and time-consuming issue.

Non-contact optical metrology solutions also fit within the concept of Industry 4.0 as they are speedier and can cover larger areas than contact devices. Fully integrated 3D optical metrology promotes fully automated closed-loop production. In addition, improvements in computer processing and optical technology mean that the sheer amount of data that can be acquired and analysed is vastly increased. 3D optical metrology solutions used in-process allow for processed data to be to be fed from the metrology system into the factory management system and this advances the concept of the smart factory considerably.

Summary

For automation to be successful in the Industry 4.0 era, data collected for monitoring and control must be reliably communicated. As a part of this trend, incorporating metrology equipment into manufacturing systems to gather data for use in intelligent decision making to prevent process variation.

More intelligent, more flexible, and faster learning metrology systems are at the heart of – and integral to – industry 4.0 and all advanced manufacturing systems. Such metrology systems promote the evolution of connected factories, and will dramatically reduce downtime while at the same time speeding up production of more innovative, better designed, and higher quality products. While there are many developments on the horizon in this area, forward-looking companies really should be looking at the advanced metrology solutions that exist on the market today and which can be used to enhance manufacturing efficiency at all levels.

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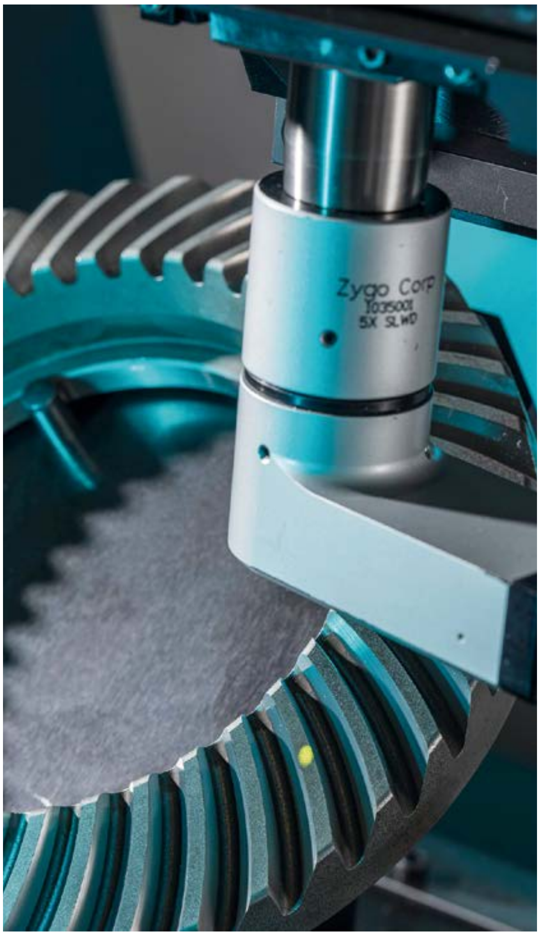

Fig. 3 Interference microscopy for measuring gear shape and texture

Authors

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Michael Schmidt, market development manager for the Zygo Corporation, has served the precision machining and industrial markets for over two decades and has extensive knowledge of non-contact optical metrology technology and application solutions development. Mike has helped numerous market-leading and global precision manufacturing companies transition and deploy optical technology and process control solutions to the factory floor.

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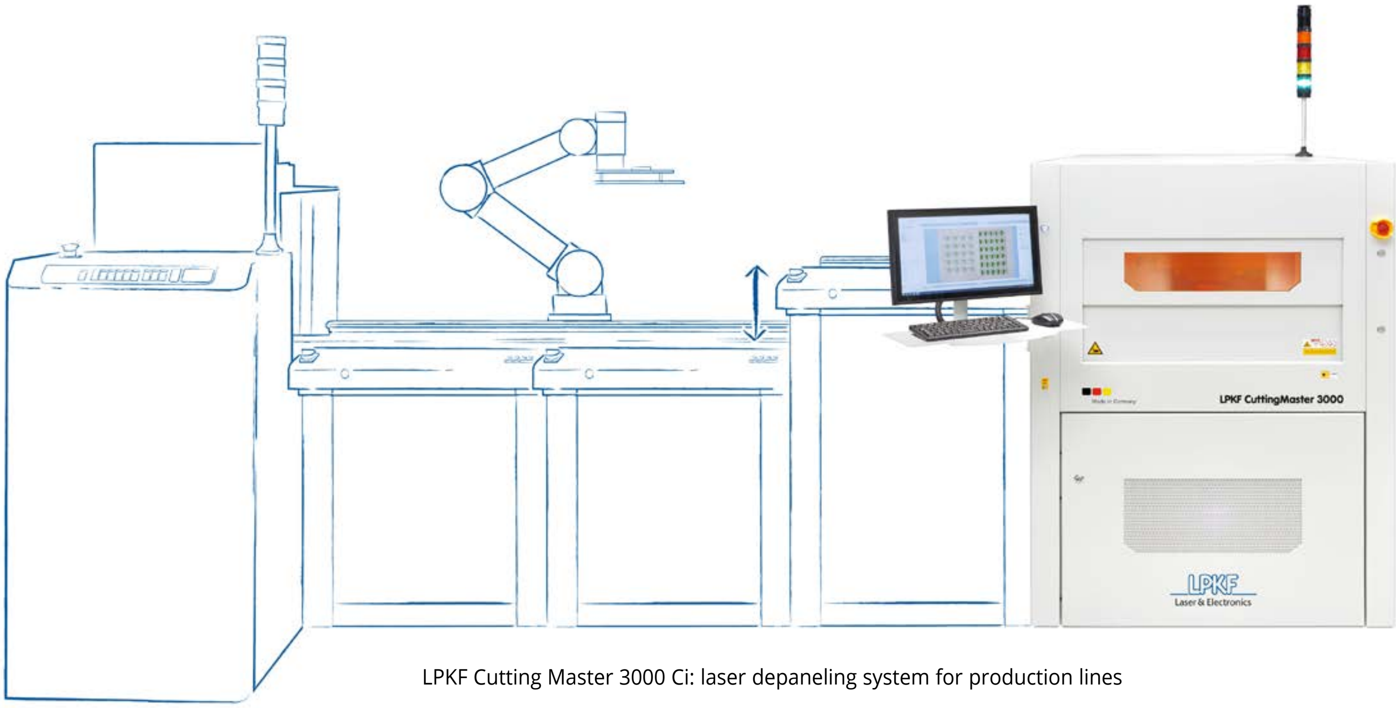
Cost-efficient laser depaneling

Why depaneling with a laser is the most efficient solution



Source all images: LPKF

LPKF Cutting Master 3000 Ci: laser depaneling system for production lines

For years now, there have been rumors going around in the electronics industry that laser depaneling is very costly. This may have been true for investments in laser machines ten or more years ago – but when considering the operating expenses, especially with newer systems, the situation looks quite different today. Meanwhile, depaneling with laser systems has become by far the most efficient method for a wide range of applications and the cutting results are excellent, which means that the highest quality standards are also met.

The trend in the price-to-performance ratio for current laser systems, especially with respect to the production of rigid printed circuit boards (PCBs), is quite obvious: The cost of depaneling based on the effective cutting speed has fallen to approximately one tenth of what it was a decade ago.

There are two main drivers for this phenomenon: on the one hand, material costs are much lower today than they were a few years ago, and on the other hand, the performance of laser systems has improved dramatically due to the integration of more powerful lasers and the more advanced process know-how developed by leading laser machine manufacturers such as LPKF.

Material savings and fewer upstream processes

Savings in printed circuit boards material of more than thirty percent on average can be achieved with the use of modern laser systems, such as LPKF's Cutting Master 3000.

This is made possible by utilizing a full-perimeter cut through the panels with the laser, rather than cutting tabs of pre-routed boards. With a full-perimeter cut, printed circuit boards can be spaced very closely together for minimal material loss; taking full advantage of the narrow kerf width of a laser tool which is typically around 0.15 mm vs. a 1 to 2 mm router bit. This eliminates the space that is otherwise occupied by pre-routing lanes around each PCB on the panel. Another advantage is the variable and exact laser guidance and the narrowest possible cut to accommodate even the most intricate geometries, ensuring optimum material utilization. Through these factors, laser systems can realize even greater savings potential, especially for smaller-sized PCBs.

In addition, the costs of upstream process steps are reduced, and users also profit from indirect savings because of the higher number of printed circuit boards per panel. The handling time for the individual PCB is reduced and human errors caused by manual handling are minimized.

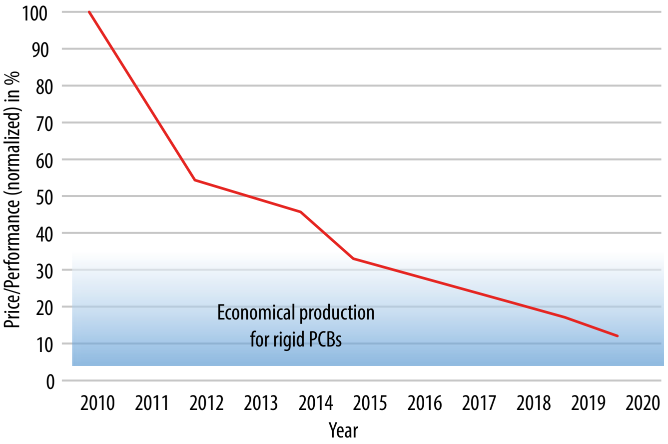


Fig. 1 Changes in price-to-performance ratio for laser depaneling systems over the period 2010 – 2020

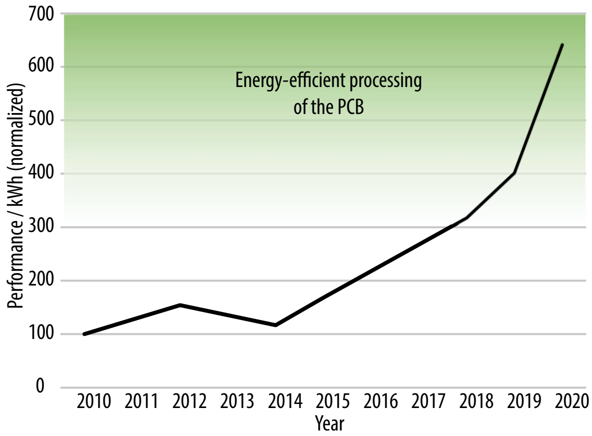


Fig. 2 Changes in energy efficiency over the period 2010 – 2020

Low operating expenses, minimal downtime

Also, unlike with milling machines, there are no significant operating expenses. This is because the laser as a tool has no mechanical wear and the quality of the laser is constant. There is no need for regular replacement of saw blades or router bits, also eliminating unproductive downtime and the cost of replacing such tools.

Preventive maintenance work can be done at longer and planned intervals because the replacement of machine wear parts is done during regular preventive maintenance deployments. Through this, the downtime can be reduced to a minimum.

Error minimization and quality improvement

Laser machines integrated into production lines are often advantageous for high volumes. Extensive automation often reduces manual errors.

Both dust and stress to the PCB are eliminated by using a laser for PCB depaneling operations, drastically improving production yield. Unlike traditional mechanical depaneling methods, laser depaneling machines do not generate milling dust that can become airborne and cause quality issues anywhere in the plant, as well as cause health problems for employees exposed to these airborne particulates. Lasers also don't create the mechanical stresses that are imparted when using a dicing saw or router, which could jeopardize the functionality of sensitive components on the circuit board or even compromise the integrity of the board itself. PCB manufacturers achieve a higher quality and a better yield if laser depaneling systems are being used. These two factors together provide a significant advantage that traditional depaneling technologies cannot equally provide.

Energy efficiency

Even if it seems at first that the energy use for depaneling was negligible for many production facilities, this factor is nowadays often considered more carefully. Over the years, the performance of the laser has risen considerably while their overall power consumption in relation has dropped significantly. This translates into a sixfold increase in overall energy efficiency – a remarkable factor that can currently only be achieved by laser technology.

Conclusion

Modern laser machines are the tools of choice when considering the above-mentioned aspects in terms of the cost-effectiveness of laser systems for the depaneling of rigid and flexible PCBs, especially for high throughput applications. These systems save on material costs and handling effort, and improve production quality, which equates to higher yield. The return on this investment is easy math.

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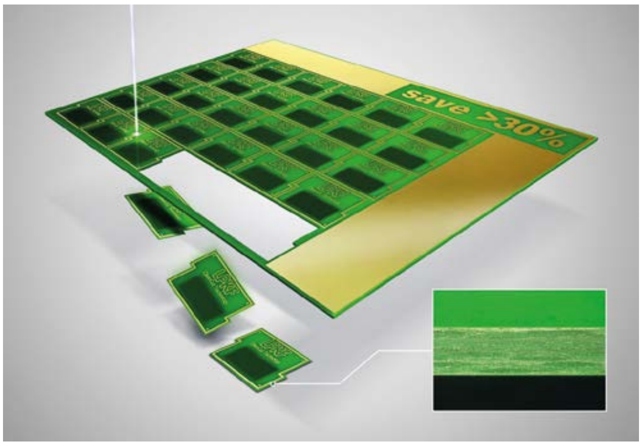


Fig. 3 Full-perimeter cutting with laser technology allows for significant materials savings.

Company

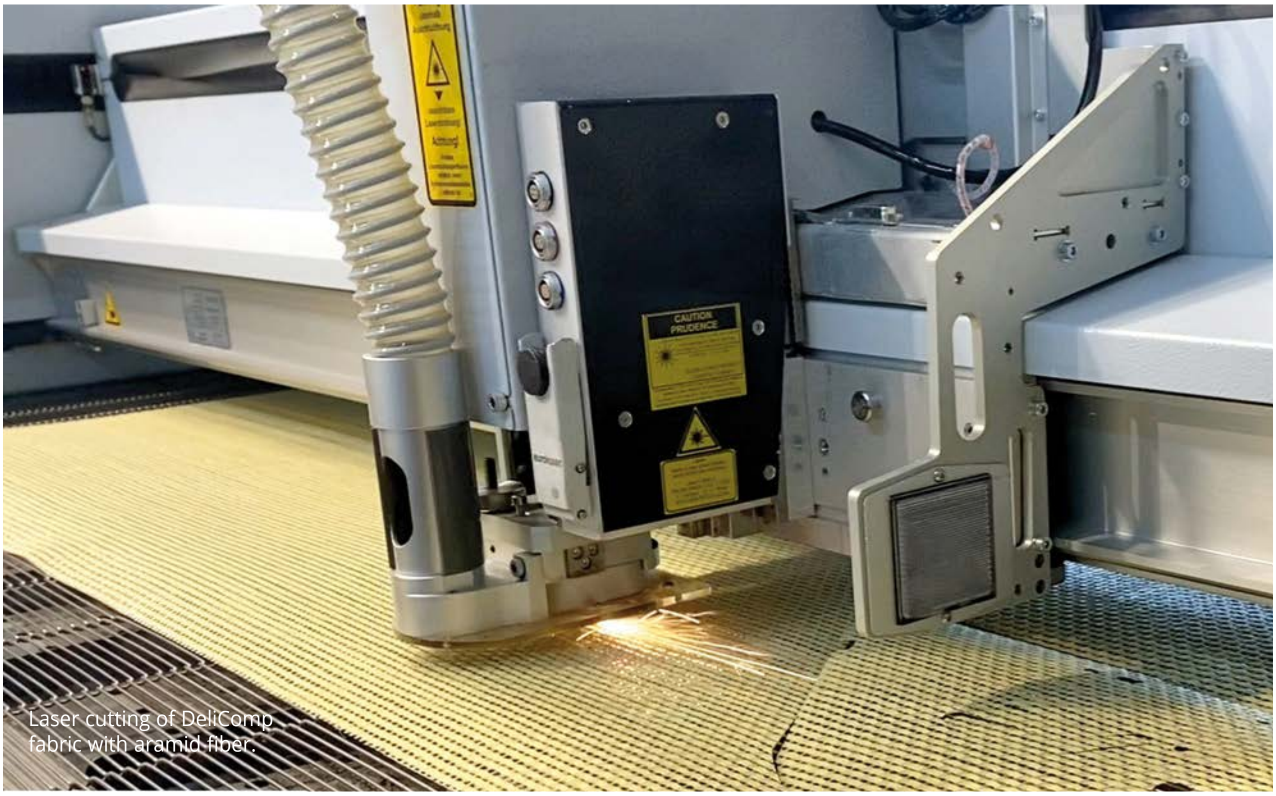
LPKF

LPKF Laser & Electronics AG is a leading provider of laser-based solutions for the technology industry. Laser systems from LPKF are key elements in the manufacturing of printed circuit boards, microchips, automotive parts, solar modules, and many other components.
Founded in 1976, the company has its headquarters in Garbsen, near Hannover, Germany, and has subsidiaries and representative offices throughout the world. Around twenty percent of the workforce is engaged in research and development.

www.lpkf.com

Cutting of composites

Fiber composite materials: When cutting and punching become too difficult – laser cutting will help



Laser cutting of DeliComp fabric with aramid fiber.

(Source all images: Delcotex & Eurolaser

Delcotex is specialized in the production of all kinds of technical textiles. With almost 300 years of textile experience, Delcotex has focused on the production of prepregs for the automotive and other transport sectors in recent years. When its composite materials have to be cut, Delcotex recommends laser cutting systems from the Lüneburg-based company Eurolaser.

Compared to conventional materials, thermoplastic prepregs can save a lot of weight and costs while optimizing the stability of components. However, the high degree of stability of the fabric has also a disadvantage: conventional knives or punches are becoming dull very quickly during usage. Consequently, this results in the recommendation from Delcotex to cut materials with laser cutters from Eurolaser. “Laser cutting gets ahead where other tools fail,” says Thomas Armbruster, head of marketing and product management at Eurolaser.

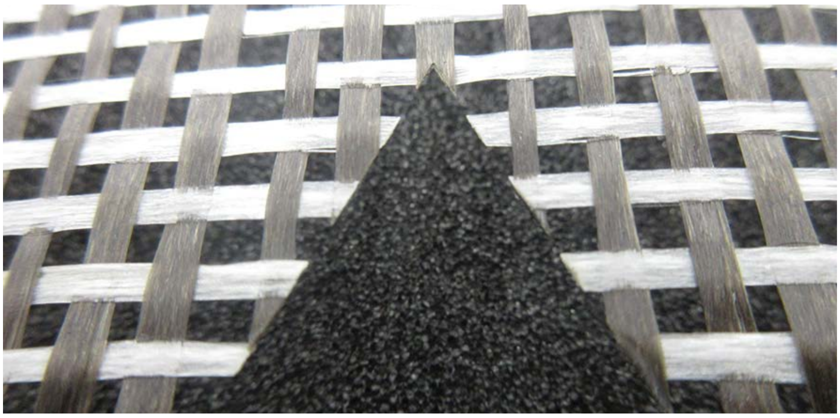
The Laser Cutter XL-1600 is available with a conveyor system and a winding unit for textiles processing.

New material enables laser cutting of prepregs

Carl Mrusek, head of business development at Delcotex explains: “Our prepregs are so stable that mechanical cutting with knives or punches does not work. The tools would be dull in a minimum of time. Economical cutting is only possible with a water jet or a laser. We are pleased with the laser cutting systems from Eurolaser as water jet cutting brings another hurdle with it. Damp edges have to be dried, which will take up to 24 hours again to dry before our customers can then, continue with the further processing of the prepregs. With the laser, the prepregs can now be cut quickly, precisely and, above all, drily. Besides, there is practically no wear of the laser.”

Good for the environment: save weight

“Especially in the course of the Fridays for Future movement and the great public interest in climate and environmental protection, weight reductions and the associated savings in fuel consumption and thus, reduced CO_2 emissions are more relevant than before,” said Mr



Only with water jet or laser an economical cutting of Delcotex prepregs is possible. Waterjet cutting presents another hurdle: moist edges must be dried before customers can further process the prepregs. With the laser, prepregs can be cut quickly, precisely and – above all – dry.

Production of prepregs at Delcotex: compared to conventional materials, thermoplastic prepregs can save a great deal of weight and also costs, while optimizing the stability of components.

Armbruster. “The composite materials from Delcotex help automotive manufacturer in particular to save massive amounts of weight in the crucial areas without having to forego the necessary material properties, such as stability and durability.” Besides, thermoplastic prepregs, which are largely made of fiberglass and polypropylene, are, compared to their expensive brother carbon, suitable for large-volume series use. Thanks to the contactless, force-free cutting, car manufacturers and especially their suppliers can save time and tool costs as well as the effort involved in assembly. Together, Delcotex and Eurolaser not only ensure a better environment for their users with the help of weight savings and process optimization, but above all, by lower operating and production costs.

Proven tandem

Delcotex recommends Eurolaser laser cutting systems to its customers. The industrial laser cutters are not only reliable, they are also durable. “In addition to being more economical than mechanical cutting, this also helps to save money in production,” says Mr Armbruster. “In return, we at Eurolaser regularly test new technical textiles from Delcotex. We issue certificates of which materials can be cut with which of our laser cutting systems. In addition, we also recommend the corresponding cutting speeds of the laser machines to our customers.”

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August 01 – 05, 2021

SPIE Optics + Photonics

San Diego, CA, USA / online

spie.org/conferences-and-exhibitions/optics-and-photonics

August 25 – 26, 2021

IVAM Hightech Summit 2021

online: www.ivam-hightech-summit.com

September 01 – 03, 2021

CIOE 2021

Shenzhen, China

www.cioe.cn

September 09 – 10, 2021

5th European Machine Vision Forum

Cork, Ireland

www.emva-forum.org

September 13 – 17, 2021

EOS Annual Meeting (EOSAM) 2021

Rome, Italy / online

europeanoptics.org/events/eos/eosam2021.html

September 14, 2021

Innovative Product Development by Additive Manufacturing

Hanover, Germany

www.lzh.de

September 14 – 17, 2021

EPHJ

Geneva, Switzerland

https://ephj.ch

September 21 – 23, 2021

122nd Annual Meeting of the DGaO

Bremen, Germany

https://dgao.de/jahrestagung

September 22 – 23, 2021

W3+ Fair Rheintal

Dornbirn, Austria

https://w3-messe.de

September 28 – 29, 2021

AI for Laser Technology Conference

online

www.ilt.fraunhofer.de

October 05 – 07, 2021

VISION

Stuttgart, Germany

www.messe-stuttgart.de/vision

October 10 – 14, 2021

International Semiconductor Laser Conference (ISLC)

Potsdam, Germany

www.islc2021.org

October 12 – 16, 2021

Fakuma

Friedrichshafen, Germany

www.fakuma-messe.de

October 18 – 21, 2021

SPIE Optifab

Rochester, NY, USA

spie.org/conferences-and-exhibitions/optifab

"100 % English edition a 100 % success"

Review: Photonics Online Meetings #3, 11 May 2021, online

The 3rd edition of the Photonics Online Meetings took place on 11 May. Marked by its 100 % English language format, the event brought together a total of 274 participants – meeting participants and congress attendees.

On the program of this day of business meetings between principals and suppliers of the photonics industry: more than 470 B-to-B meetings were held with a satisfaction rate of more than eighty percent and 15 product webinars were presented by Polytec France, Dioptic, ACM Coatings, Mitutoyo, Schott, Lambda-X, RP Photonics, Hamamatsu Photonics France, AEMtec, Argotech, Lumibird, Photon Lines, Alpha-RLH and Graphene Flagship. POM#3 provided an opportunity to meet European players in the photonics industry, R&D and innovation to identify skills and technological solutions, present projects and exchange with principals and partners, develop business networks, target public or private funders, and hold virtual meetings.

Opening of the Photonics Online Meeting #3 (Source: Photonics France)

On the strength of this success, a 4th edition is already planned for November 2021 with a reinforced desire to bring together the European players in the photonics sector. The objective will again be to facilitate and support meetings in these current uncertain times by providing solutions to future challenges.

www.photonics-france.org

A three-day industry exhibition with conference and a physics job fair

Review: WIN>DAYS, 7 – 9 June 2021, online

The trade journal group of Wiley Verlag, including PhotonicsViews, inspect, messtec drives automation, GIT Sicherheit, GIT Security and Management & Krankenhaus as well as Ernst & Sohn have held the second virtual 'Wiley Industry Days', or WIN>DAYS for short, with renowned companies and institutions. Exhibitors from the fields of security, safety, civil engineering and architecture, automation, machine vision, photonics, hygiene and healthcare presented their innovations and services in the halls of the virtual exhibition center. Visitors could view products, solutions and presentations and learn about the latest trends in their industries. WIN>DAYS hosted a conference program taking place in five digital auditoriums.

Just like the first instance in November 2020, the exhibition center was set up like a physical trade fair. The lobby had all the information visitors need to orient themselves. Visitors could post chat requests to each other throughout the exhibition center. Each participant had an overview of who was on the grounds, in the various rooms, or at the stands at all times. Visitors could see a list of stand personnel and contact exhibitors via video chat, text chat, or email. They could switch to a private room for a video chat if they require.

Conference Program

The focus of the event was the exhibition and networking – accompanied by an extensive conference program. Panel discussions with high-profile guests and selected keynote speakers provided information on the latest developments from industry and research. In addition, exhibitors invited visitors to give presentations. The digital conference program could be viewed via the auditoriums – interested parties were able to click directly into the lectures.

The exhibition halls, and also Hall B – automation, machine vision, and photonics – hosted high-ranking companies, research institutions, and industry associations. Among the many live contributions, the following companies, institutions and organizations gave photonics-related presentations (in alphabetical order): Comsol Multiphysics GmbH, Dr Thorsten Koch (CEO) and Dr Andreas Bick (Applications Engineer), EPIC – European Photonics Industry Consortium, Tracey Vanik (Head of Photonics Market Research), Fraunhofer Institute for Laser Technology ILT, Christian Knaak (Research Associate), Hamamatsu Photonics, Florian Friedl (Group Leader Automotive), Laservision, Hans Christan Meedt (Regional Sales Manager), Spectaris, Dr Wenko Süptitz (Head of Photonics Division).

Source: Wiley

Hall B – automation, machine vision, and photonics

The following companies presented career opportunities in their companies during this year's WIN>DAYS: Horn & Company, Dr Christoph Hartl, Senacor, Jonas Hoppmann, and Zeiss, Dr Jasmin Biehler, Dr Christopher Hinz, and Fabian Sibbers.

https://wileyindustrydays.com

Positive feedback to online format

Review: EMVA Business Conference Special Edition 2021

Source: EMVA

With a participation of 135 participants from 23 nations, the 19th EMVA Business Conference Special Edition 2021 took place online. A total of 20 speeches, two fireside chats and two CEO/Management panel discussions covered virtually all current economic and technical topics that the machine vision world is currently dealing with. About 90 virtual bilateral video meetings were arranged between conference attendees during the individual B2B sessions between conference attendees before and after the conference program in the afternoons.

The top-class panel on the second conference day discussed the current status of Industry 4.0, and stated that the term has already become a standard itself with AI and machine vision as the core components, such as in generating digital twins. However, industrial business models are often not so disruptive as in end-user business - such as when smart phones triggered a paradigm shift, for example - but prefer to improve existing strategies rather than developing new ones. According to the panelists, more data also requires increasing use of AI and digitalization, which automatically contributes to decarbonization. Vision, as it was stated, can provide the right data at the right time to make the right decision in Industry 4.0.

Being a megatrend in the machine vision industry, AI was present in various technical parts of the conference sessions. The keynote on the second day given by IBM Benelux CTO Wouter Denayer reflected on the current developments pledged to change the fundamental structure of neural networks towards Neural Symbolic AI Systems. Simply making networks bigger would not help in future and the increase in accuracy for training AI is no longer proportional to the amount of energy input required and pollution generated, which makes the carbon footprint of AI unjustifiable. Or as EMVA President Chris Yates put it in his conference wrap-up: “With great power comes great responsibility”.

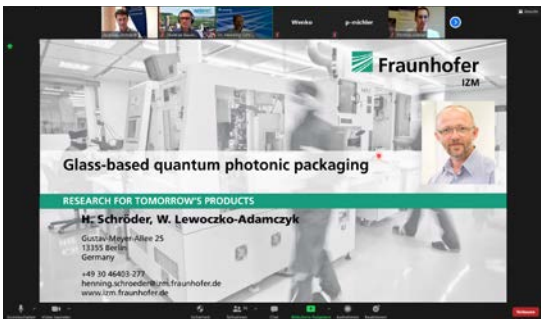
This conference also provided room to put early-stage innovators in the focus: no less than six companies in the initial or post start-up stage presented their innovations which circled around the big topics of AI and deep learning, logistics and complex inspection tasks

www.emva.org

Networking and co-operation as success factor

Review: Quantum Technology – The Participation of German Industry, 22 June 2021, online

The third virtual meeting of the nationwide expert group Quantum Technologies of Photonik Deutschland – Photonics Germany provided about eighty participants with insights on the topic “Quantum technologies and the participation of the German economy”.



Source: Photonics Germany

One of the expert talks: Henning Schröder (IZM) “Glass-based quantum photonic packaging”

Thomas Bauer, chairman of OptecNet Germany, and Dr Wenko Süptitz, head of photonics at Spectaris, welcomed the participants and introduced the program consisting of four expert presentations.

Henning Schröder, Fraunhofer Institute for Reliability and Microintegration (IZM), gave an insight into glass-based quantum photonic packaging and additionally highlighted opportunities for spin-offs and start-ups. The following presentation of Andreas Bülter, PicoQuant, dealt with the topic “Single Photon Counting in Optical Quantum Technologies”.

Subsequently, Dr Robert Axmann of the German Aerospace Center (DLR) introduced the DLR initiative for the promotion of quantum computing. Funded by the Federal Ministry for Economic Affairs and Energy (BMWi), new quantum computers can be developed and an economic environment consisting of industrial companies, research institutions and start-ups can be created.

Thomas Gläßer, project manager at Photonics BW, concluded by presenting the “Agenda Quantum Systems 2030” of the Quantum Systems program committee consisting of numerous stakeholders. A long-term funding strategy is needed to be able to apply and to exploit existing competencies and economic advantages. The research results should serve as a basis for the development of new products and services in quantum technology. The involvement of a wide variety of participants from industry, research institutes and politics is important to ensure successful implementation. With specialist events on quantum technologies, Photonics Germany promotes the networking of these players and is included accordingly in the Agenda Quantum Systems 2030.

After the presentations, a discussion on future activities within the expert group took place. The next meetings are planned for the fall of 2021, again either virtually or possibly in hybrid form.

Photonics Germany is the alliance of Spectaris and OptecNet Deutschland. PhotonicsViews is its official publishing medium since April 2021.

https://photonics-germany.de

Event concludes with a positive outlook for the photonics industry

Review: LASER World of PHOTONICS Industry Days, 21 – 24 June 2021, online

The global market for lasers and laser systems will grow by 6 % in 2021. This optimistic forecast issued by the highly respected analytical firm Optech Consulting was one of the highlights of the Laser World of Photonics Industry Days that was held as an entirely digital event from June 21 – 24. A total of 1,525 people learned about market figures and the latest technology trends in the photonics industry and networked with colleagues. The digital event was closely integrated into the online version of the World of Photonics Congress 2021, which was simultaneously attended by about 2,450 scientists.

The Industry Days shortened the wait for the regular Laser World of Photonics trade fair that will be held in 2022 in Munich once again. The online event began with a keynote address by Dr Reinhard Genzel, Nobel laureate in physics. The professor discussed how he was able to prove Albert Einstein's general theory of relativity by observing black holes.

Part of the virtual 'Laser' roundtable (Source: Messe München)

The focus of day 2 was the market performance of the photonics industry. Dr Arnold Mayer of Optech Consulting reported that global sales of laser materials processing systems declined only slightly during 2020 as a result of the Covid-19 pandemic – to 15 billion euros. The total still exceeded the level of 2017 and all other years that preceded it. Mayer forecasts 6 % growth for 2021 (in euro-denominated terms).

The German photonics industry has suffered little and even performed well during the Corona crisis, Joerg Mayer, the managing director of the Spectaris trade association noted. After the industry's revenues declined by 1.1 % in 2020, he expects to see an increase of 9.4 % in 2021. The reason for the positive turnaround: photonics applications are the heart of such growth industries as semiconductors and e-mobility.

"We are really happy that we could provide the entire photonics industry with a place to gather," said Dr Reinhard Pfeiffer, the deputy chairman of the board at Messe Muenchen.

https://world-of-photonics.com

"The largest digital event for the photonics industry succeeds at its second attempt"

Review: PHOTONICS+, 29 – 30 June 2021, online

On 30th June, the 2nd Photonics+ Virtual Exhibition and Conference ended successfully. For two days, more than 140 players from the photonics world met over 2,072 participants and potential customers at the last industry get-together before the summer break to discuss new partnerships and projects together. A partner of the event is EPIC, Europe's largest photonics industry network. The companies appeared in digital booths and provided a product presentation.

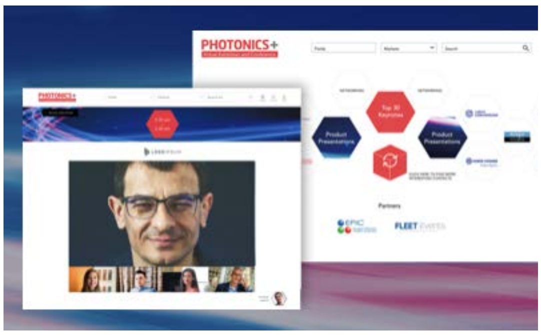
The emphasis of the live event, which took place from 1 to 5 pm both days, was personal exchange in 1:1 video chats. Not only exhibitors but all active users of the platform were able to communicate with each other. The ten keynotes, which were broadcast live from all over the world, were again very well received. Renowned international speakers from Jenoptik, Coherent, PicoQuant, Q.ant, Avantes and AEMtec, among others, provided insights into the key requirements of the user industries. The networking rooms that, amongst others, covered the topics of optics, electronics/semiconductors and life sciences provided the opportunity for all participants to make spontaneous contact. CEOs and CTOs were additionally invited by EPIC for exclusive networking.

"We firmly believe that digital events will remain an integral part of the event landscape and will complement and enrich face-to-face events in the future. With Photonics+, which is based on our own xircus event platform, we have created a perfect digital facility for B2B and B2C," says a delighted Joerg Brueck, business director at event organizer Fleet Events.

Carlos Lee, director general of the European Industry Consortium, EPIC, adds: "I really like the platform. The opportunity to network live with new contacts in an uncomplicated way is a business driver for our member companies. Together with Fleet Events, we will continue to work on expanding digital events with qualified attendees and high value."

More Photonics+ events are planned for 2021 and 2022 and will be announced in due time.

www.photonicsplus.com



Source: photonicsplus.com

Preview: IVAM Hightech Summit 2021

25 – 26 August 2021, online

This year, the IVAM Hightech Summit will take place as a purely digital event. It is the central microtechnology conference where international experts from micro and nanotechnology come together once a year. The latest developments and products are presented and the challenges of the future are intensively discussed. In recent years, digitalization has been the central theme of the event.

The primary aim of the event is to establish contacts efficiently. Companies and institutes will have the opportunity to present their products, find customers, suppliers and research partners and talk about upcoming projects in the virtual space. At the heart of the event will be the technical conference program focusing on microfluidics, medical technology, wearables, organic electronics, and optics and photonics. The digital supporting program includes virtual networking areas as well as an exhibition area with company presentations and live video chats.

Interested companies can now register for 'Hightech Packages' at the IVAM Microtechnology Network. In addition to a presentation slot in the program and conference tickets for employees, the packages also include a digital 'Brand Space' with upload and presentation options as well as live video chat functions and guaranteed leads by capturing the contact details of all interested visitors. IVAM members as well as members of partner associations receive the conference packages at a preferential price. Extended sponsorship packages are also available.

www.ivam-hightech-summit.com

Preview: 122nd DGaO Annual Meeting

21 – 23 September 2021, Bremen, Germany

With its annual conference 2021, which has been postponed due to the pandemic, the German Society for Applied Optics (DGaO) is taking a step towards normality by holding the conference in the Atlantic Hotel Universum in Bremen, Germany.

A varied program of around one hundred scientific lectures and object posters offers the opportunity to revive the personal exchange and discourse that is so important for science. As a relaxed face-to-face meeting with an unlimited number of visitors is still not possible due to the pandemic situation, the annual meeting this year will be held as a hybrid event with a maximum of 140 participants at the venue. The scientific lecture program can be followed in person or via the Internet. Poster authors can present their scientific results on the Internet.

An exciting scientific program has been set up, thanks to the great voluntary commitment of the members of the program committee and especially the conference chair Prof Ralf Bergmann and the chairman of the program committee Prof C Faber. The main topics of the conference are measurement technology, display and lighting technology, sensors and calibration procedure, additive manufacturing, optics design, optical materials and their adaptions, microstructuring and characterization, machine learning and computational imaging. These topics will be addressed in 6 invited plenary lectures, 73 submitted lectures and 19 scientific posters.

Special highlights of the conference are the Fraunhofer lecture by Prof Katja Poppenhäger from the Leibniz Institute for Astrophysics, Potsdam, with the title "Exoplanets – what light curves and spectra tell us about other solar systems" on September 22nd, 2021 at 7 pm, as well as the presentation of the "DGaO Young Scientist Award" to five young scientists. As always, the scientific program is accompanied by an exhibition of the industrial supporters of the DGaO. We look forward to the active participation of numerous scientists from applied optics.

https://dgao.de/jahrestagung

Preview W3+ Fair Rheintal

22 – 23 September 2021, Dornbirn, Austria

For the second time, the W3+ Fair trade fair is calling companies from the optics, photonics, electronics and mechanics sectors to the Dornbirn exhibition center. The high-tech suppliers will be on site to network and to develop forward-looking innovations together with user industries. The new accompanying N-Tec Talks congress will provide visitors with the latest knowledge.

After the cancellation in 2020 due to Corona, the high-tech W3+ Fair Rheintal is to open this year's high-tech fall season on September 22 and 23, 2021 at the Dornbirn Exhibition Center. At the trade event, developers and technology providers from optics, photonics, electronics and mechanics will network and establish contacts in key user industries such as medical technology, life science, mechanical engineering or automotive. Experts from enabling technologies will be looking for new technological developments and many companies are looking forward to the resumption of face-to-face events and the opportunity to make new business contacts. There are already commitments from major regional players such as SwissOptic, Evatec, Rysearch and CSEM from Switzerland, Swarowski

Optik from Austria and Optics Balzers from Liechtenstein. But many companies from Germany, such as Optotech and scia Systems, have also signed up.

A central component of the trade show will be the new, accompanying high-tech congress N-Tec Talks, which is open to all trade show participants free of charge. Here, prominent specialists will present trends and product innovations of equal interest to product managers, developers or buyers.

Effective security measures

Rapidly reducing restrictions mean that normal trade show activities can be expected for the end of September. Organizer Fleet Events will implement the hygiene measures required at that time together with the Dornbirn Exhibition Center. The organizer has still had to cancel a previously planned event, the W3+ in Wetzlar.

www.fleet-events.de

Preview: Vision 2021

5 – 7 October 2021, Stuttgart, Germany

The current Corona regulations of the state of Baden-Württemberg enables Messe Stuttgart to hold the international trade fair for machine vision in a way that is safe for everyone involved, the organizer is confident. The basis is a four-stage plan that keeps the safety level stable even with increasing incidence figures.

For example, the corona safety procedures, now familiar from everyday life, will be implemented at the exhibition center, ensuring that all participants are verifiably vaccinated, recovered or tested negative. Corresponding testing capacity is also planned on site. In addition, a general mask obligation applies - the mask can be removed in the restaurant or at a catering stand as well as in the outdoor areas of the trade fair.

To ensure that visitors can relax and comply with the distance rules, the aisles are four meters wide and the areas for catering, networking and forums have been extended. In addition, building management will ensure adequate fresh air exchange.

"Now that we have a planning basis in the form of the current Corona Ordinance issued by the State of Baden Wuerttemberg on June 28, we are doing everything we can to make 2021 a successful Vision year!" promises Florian Niethammer, project manager at Messe Stuttgart. "Despite the dynamic pandemic situation and realistic expectations, we sense enormous anticipation and a great desire among all those involved that the industry can finally meet again in person," he adds.

Interested parties who are unable to travel will find all exhibiting companies in the online exhibition directory for the trade fair. In addition, Messe Stuttgart will broadcast the 'Industrial Vision Days' conference live and on demand for the first time. Also new are the Motek and parts2clean trade fairs, which will be held in parallel.

At the center of this year's supporting program are the Industrial Vision Days innovations and new developments in machine vision will be presented and trends discussed here. This year, the Vision Award will also be presented for the first time on the big stage. This prestigious award will be presented by a distinguished jury to honor the best innovation in the field of machine vision.

www.messe-stuttgart.de

Preview: 27th International Semiconductor Laser Conference (ISLC)

10 – 14 October 2021, Potsdam, Germany / online

The renowned International Semiconductor Laser Conference (ISLC) will be held in Germany – for the first time in nineteen years and in person. The Berlin-based Ferdinand Braun Institute (FBH) will host the ISLC as a hybrid event, supported by the IEEE Photonics Society as technical sponsor. This makes the ISLC one of the very first in-person international laser conferences since the Covid-19 outbreak began.Those interested in the conference who cannot travel to the event are welcome to participate online.

The ISLC is dedicated to the latest developments in semiconductor lasers, amplifiers and LEDs. It represents excellence from all global regions and in all areas of current semiconductor laser research. The program committee has selected the top 100 papers for oral and poster presentations from the conference submissions. An extensive program complements the conference, including renowned speakers and workshops on topics such as automotive lidar and photodetection.

The ISLC has more than 50 years of tradition, attended by a highly international audience and with locations cycling between the Americas, Asia/Australia and Europe/Mid-East/Africa regions every two years. Since its founding, many new and ground-breaking semiconductor devices have been first presented first at this conference. The ISLC was last in Germany in 2002.

Topics include: semiconductor optical amplifiers, silicon compatible lasers, VCSELs, photonic band-gap and microcavity lasers, grating controlled lasers, multisegment and ring lasers, quantum cascade and interband laser, sub-wavelength scale nanolasers, mid IR and THz sources, InP, GaAs and Sb materials, quantum dot lasers, high power and high-brightness lasers, GaN and ZnSe based UV to visible lasers and LEDs, communications lasers, and semiconductor integrated optoelectronics.

www.islc2021.org

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18 January 2021 Advertising deadline
08 December 2020 Editorial deadline

Focus: Photonics West
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- Biophotonics
- Laser sources

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16 April 2021 Publishing date
12 March 2021 Advertising deadline
15 February 2021 Editorial deadline

- Optical measurement and testing
- Industrial machine vision: cameras, software, applications
- Optical systems and components

3

18 June 2021 Publishing date
14 May 2021 Advertising deadline
16 April 2021 Editorial deadline

Focus: Laser World of Photonics
- Laser optics
- Microscopy
- Optical measurement and testing
- → **with Company Profiles**

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01 August 2021 Publishing date
30 June 2021 Advertising deadline
02 June 2021 Editorial deadline

e-Special / digital only
- Simulations and Optical Design
- Fibers and fiber optics
- Optical systems and components

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01 October 2021 Publishing date
31 August 2021 Advertising deadline
04 August 2021 Editorial deadline

- Laser plastics processing
- Optical systems and components
- Laser cutting and welding

Trade fairs
Blechexpo
Schweisstec
VISION

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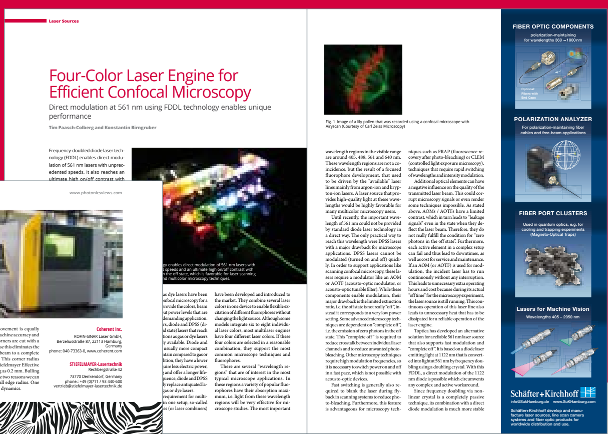
08 November 2021 Publishing date
05 October 2021 Advertising deadline
08 September 2021 Editorial deadline

- Quantum technologies
- Additive manufacturing
- Medical applications

Trade fairs
COMPAMED
formnext



Technical Article

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

Application Report

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

Product Report

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

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Company Index

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OPTICS • PHOTONICS • LASER TECHNOLOGY

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